

Sleep Inertia Project: Progress Report ver. 1.1 α

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1 Introduction

The aim of the report is to show novel methods in functional neuroimaging [1] of sleep inertia stages with emphasis on novel time-frequency preprocessing meth-

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ods [2, 3, 4, 5, 6] and models of effective connectivity evaluated by dynamic causal modeling and econometric models (such as Granger causality and related methods) [7, 8, 1]

2 Methods

The EEG signals from two conditions #1 and #2 for all experimental factors *EEG08* till *EEG17* for the following channels: *C4 – A1*; *C3 – A2*; *Fz – A1*; *Pz – A1*; *Oz – A2* where first preprocessed with EMD adaptive filtering procedures (removing mostly muscle artifacts in lower and high frequency ranges). The so obtained *clean EEG* signals were further with interdependence measures.

2.1 Empirical Mode Decomposition (EMD) EEG Preprocessing

...to be added soon...

2.2 Signals Interdependence Evaluation

Suppose that we are given n signals $X_1(k), X_2(k), \dots, X_n(k)$, each stemming from a different channel. We consider the multivariate autoregressive (MVAR) model:

$$X(k) = \sum_{l=1}^p \mathbf{A}(l)X(k-l) + E(k), \quad (1)$$

where $X(k) \triangleq (X_1(k), X_2(k), \dots, X_n(k))^T$, p is the model order, the model coefficients $\mathbf{A}(l)$ are $n \times n$ matrices, and $E(k)$ is a zero-mean Gaussian random vector of size n . In words: Each signal $X_i(k)$ is assumed to linearly depend on its own p past values and the p past values of the other signals $X_j(k)$. The deviation between $X(k)$ and this linear dependence is modeled by the noise component $E(k)$. Model (1) can also be cast in the form:

$$E(k) = \sum_{l=0}^p \tilde{\mathbf{A}}(l)X(k-l), \quad (2)$$

where $\tilde{\mathbf{A}}(0) = \mathbf{I}$ (identity matrix) and $\tilde{\mathbf{A}}(l) \triangleq -\mathbf{A}(l)$ for $l > 0$. One can transform (2) into the frequency domain (by applying the z -transform and by substituting $z \triangleq e^{-2\pi i \Delta t}$, where $1/\Delta t$ is the sampling rate):

$$X(f) = \tilde{\mathbf{A}}^{-1}(f)E(f) \triangleq \mathbf{H}(f)E(f). \quad (3)$$

The power spectrum matrix of the signal $X(k)$ is determined as

$$\mathbf{S}(f) \triangleq X(f)X(f)^* = \mathbf{H}(f)\mathbf{V}\mathbf{H}(f), \quad (4)$$

where \mathbf{V} stands for the covariance matrix of $E(k)$.

2.2.1 Coherence (COH)

The coherence function quantifies linear correlations in frequency domain. One distinguishes the magnitude square coherence function and the phase coherence function. The former is dened as:

$$c(f) \triangleq \frac{|X(f)Y^*(f)|^2}{|X(f)||Y(f)|}, \quad (5)$$

where $X(f)$ and $Y(f)$ are the Fourier transforms of x and y respectively; Y^* is the complex conjugate of $Y \in \mathbb{C}$, and $|Y|$ is the magnitude of Y . The phase coherence function is dened as

$$\phi(f) \triangleq \arg[X(f)Y^*(f)]. \quad (6)$$

In practice, one often subdivides the signals x and y in M segments (of equal length), and determines $c(f)$ by averaging over those segments:

$$c(f) \triangleq \frac{|\langle X(f)Y^*(f) \rangle|^2}{|\langle X(f) \rangle||\langle Y(f) \rangle|}, \quad (7)$$

where $\langle \cdot \rangle$ denotes averaging over the M segments. Along the same lines, the phase coherence $\phi(f)$ is often computed as:

$$\phi(f) \triangleq \arg[\langle X(f)Y^*(f) \rangle]. \quad (8)$$

Note that both $c(f)$ and $\phi(f)$ depend on the frequency f .

As for properties of coherence, its estimated value ranges between 0 and 1. For a given frequency. A value of 0 indicates that the activities of the signals in this particular frequency bin are linearly independent, whereas a maximum value of 1 gives the top linear correlation for such particular frequency bin.

2.2.2 Directed Transfer Function (DTF)

$$\gamma_{ij}^2(f) \triangleq \frac{|H_{ij}(f)|^2}{\sum_{j=1}^m |H_{ij}(f)|^2} \in [0, 1], \quad (9)$$

where the (frequency-dependent) normalization is chosen so that $\gamma_{ij}^2(f)$ quanties the fraction of inow to channel i stemming from channel j .

2.2.3 Partial Directed Coherence (PDC)

$$P_{ij}(f) \triangleq \frac{\tilde{A}_{ij}(f)}{\sqrt{\sum_{i=1}^m |\tilde{A}_{ij}(f)|^2}} \in \mathbb{C}, \quad (10)$$

2.2.4 Direct Directed Transfer Function (dDTF)

$$\chi_{ij}^2(f) \triangleq F_{ij}^2(f)C_{ij}^2(f) \in [0, 1], \quad (11)$$

which is non-zero if the connection between channel i and j is causal (non-zero $F_{ij}^2(f)$) and direct (non-zero $C_{ij}^2(f)$).

3 Preliminary pairwise channel synchrony evaluation results

3.1 Magnitude coherence

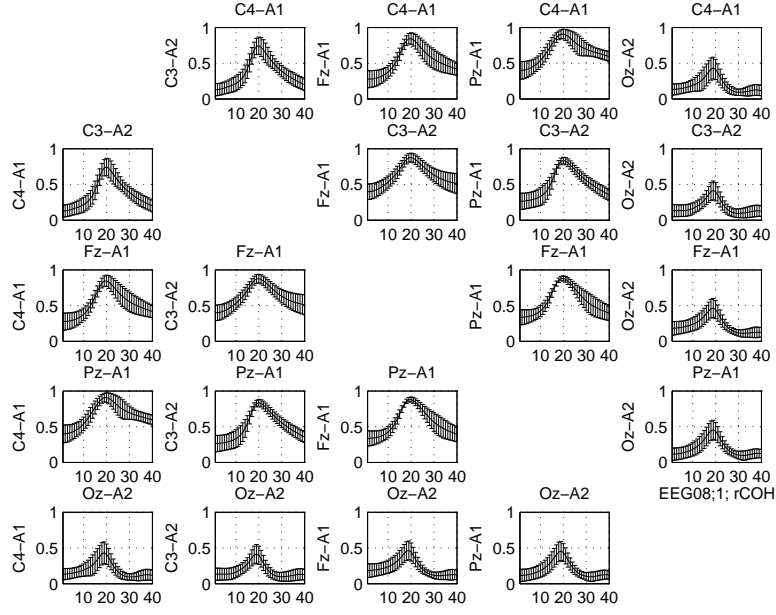


Figure 1: Magnitude coherence as in (5): Condition #1 & factor EEG08. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

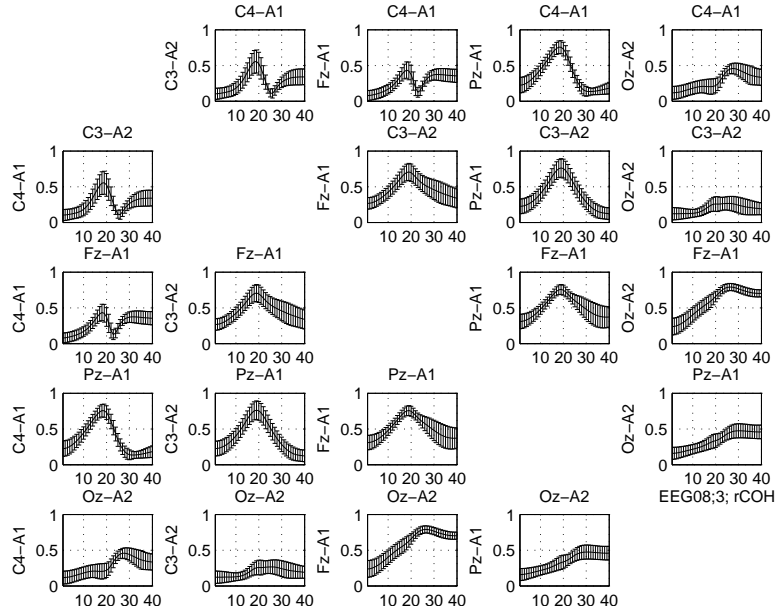


Figure 2: Magnitude coherence as in (5): Condition #3 & factor EEG08. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

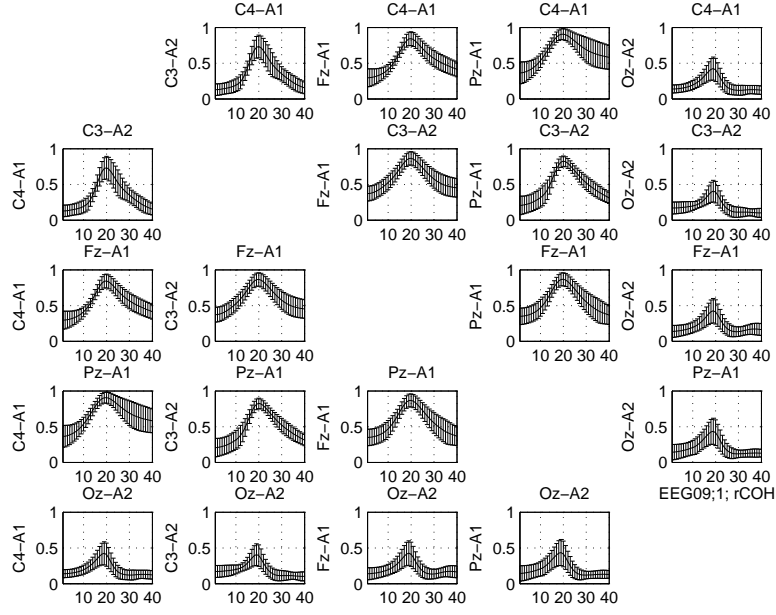


Figure 3: Magnitude coherence as in (5): Condition #1 & factor EEG09. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

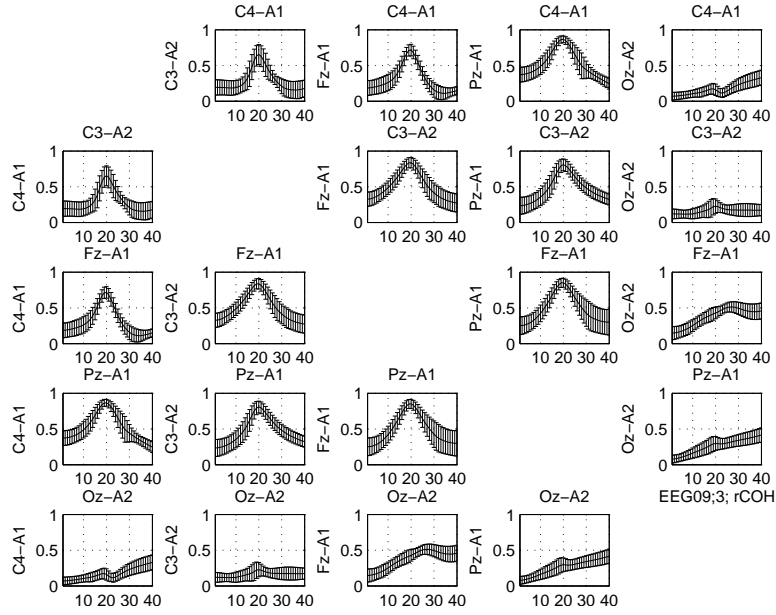


Figure 4: Magnitude coherence as in (5): Condition #3 & factor EEG09. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

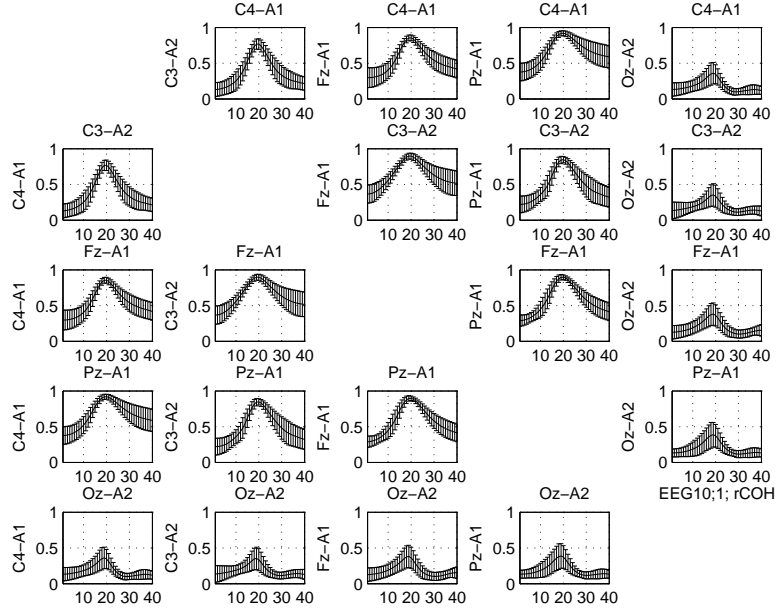


Figure 5: Magnitude coherence as in (5): Condition #1 & factor EEG10. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

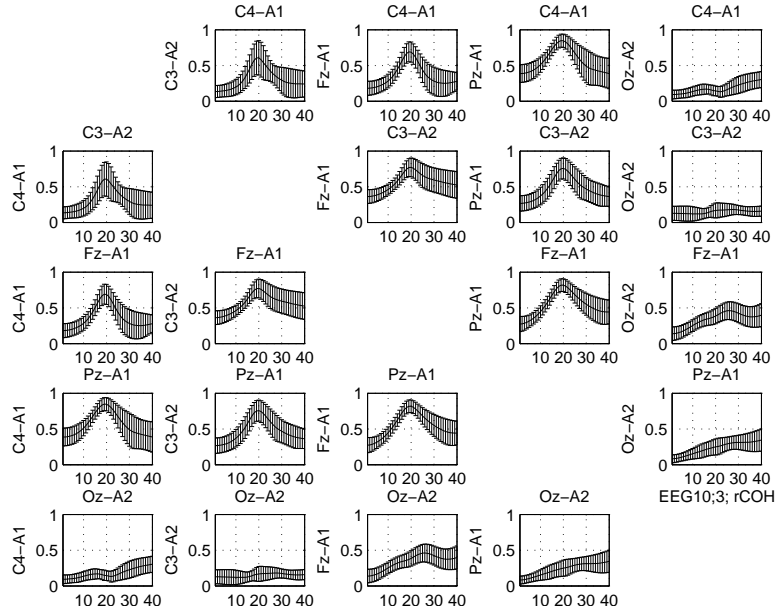


Figure 6: Magnitude coherence as in (5): Condition #3 & factor EEG10. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

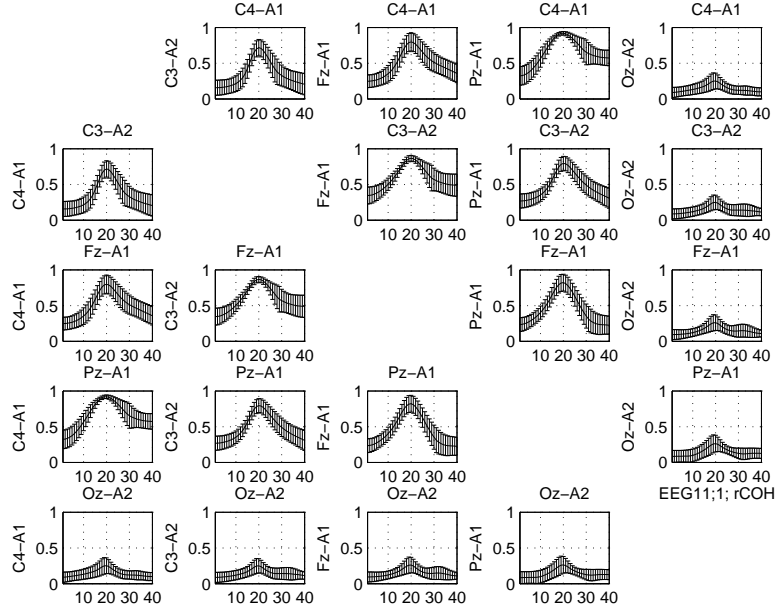


Figure 7: Magnitude coherence as in (5): Condition #1 & factor EEG11. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

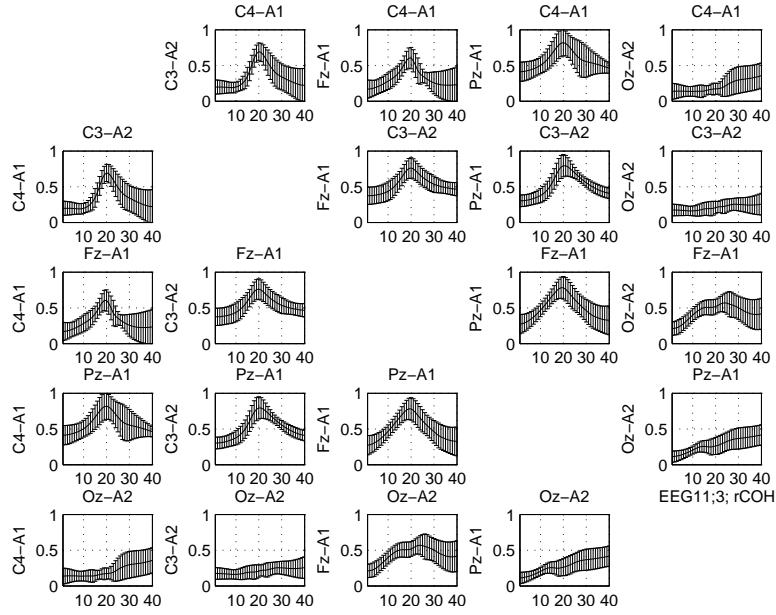


Figure 8: Magnitude coherence as in (5): Condition #3 & factor EEG11. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

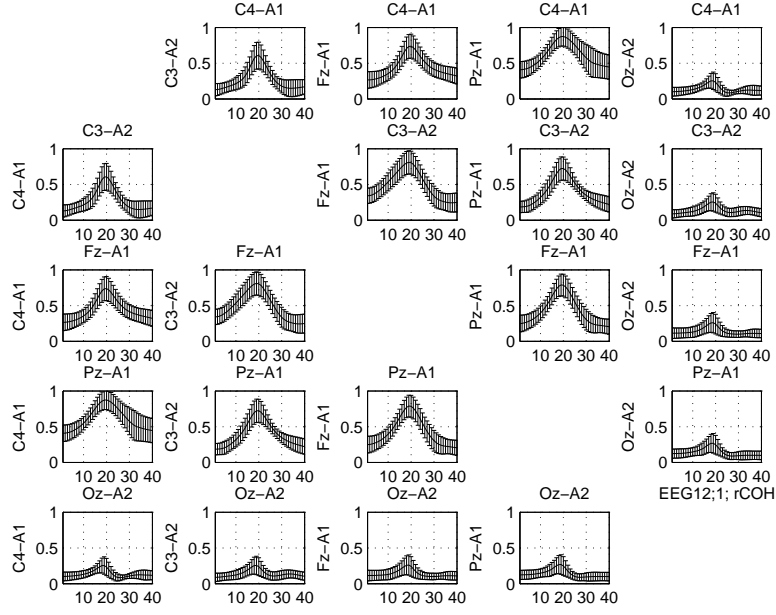


Figure 9: Magnitude coherence as in (5): as in (5): Condition #1 & factor EEG12.*X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

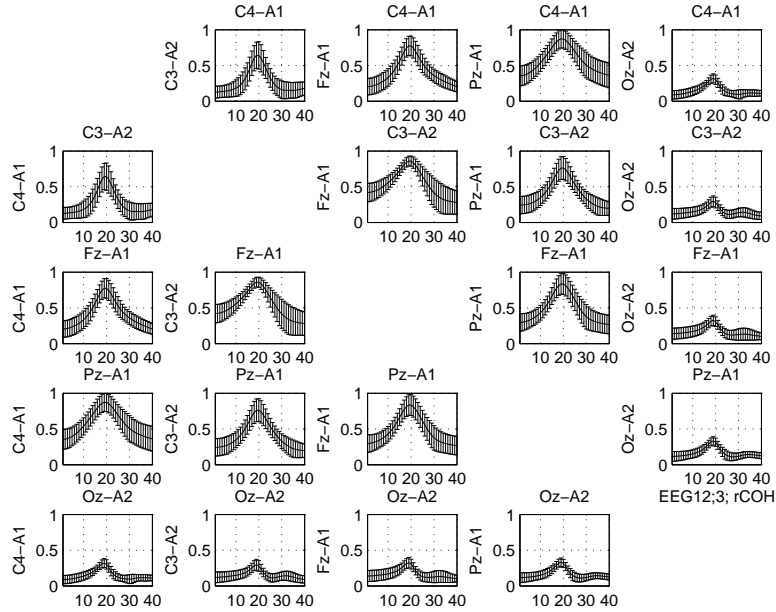


Figure 10: Magnitude coherence as in (5): Condition #3 & factor EEG12.*X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

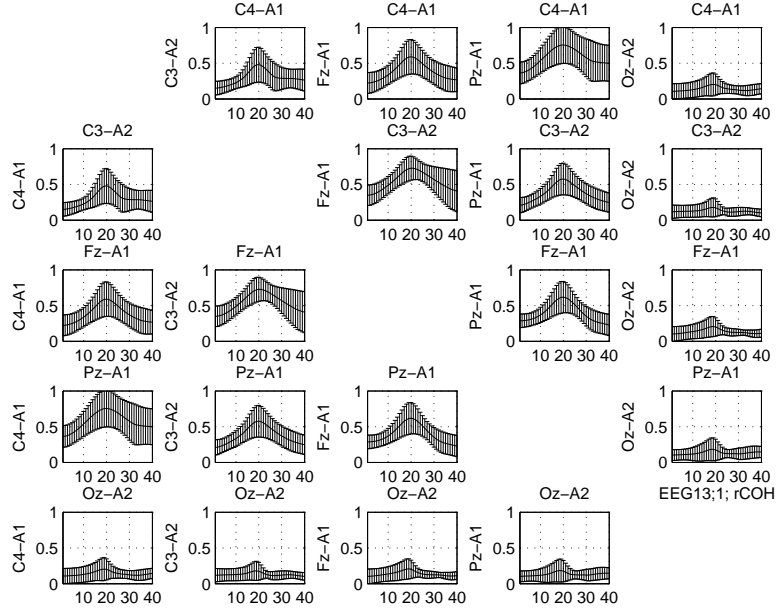


Figure 11: Magnitude coherence as in (5): Condition #1 & factor EEG13. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

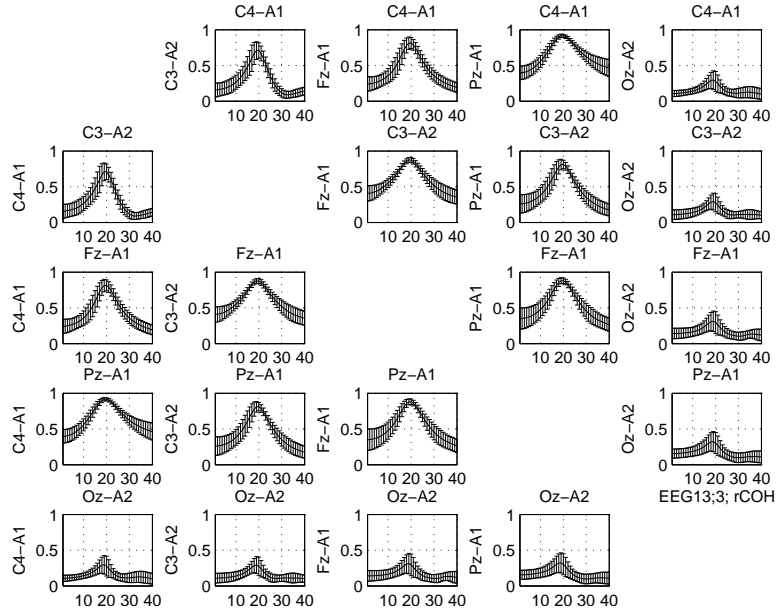


Figure 12: Magnitude coherence as in (5): Condition #3 & factor EEG13. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

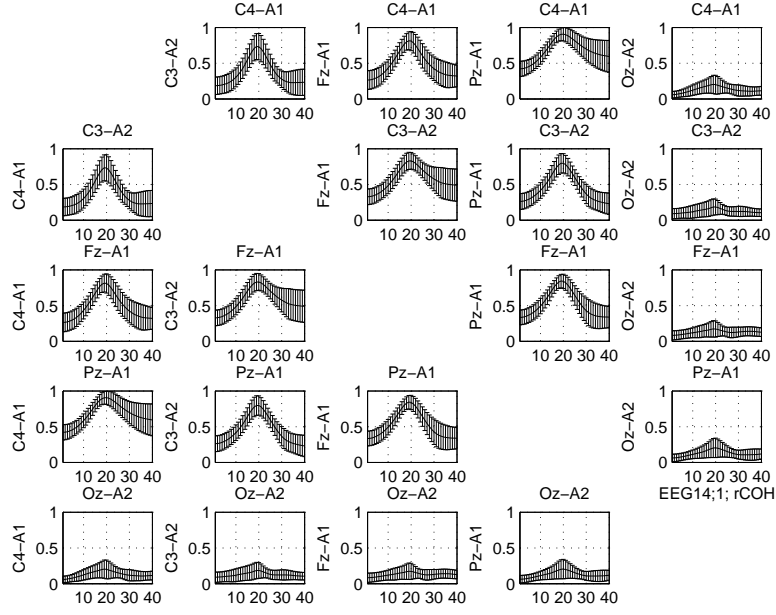


Figure 13: Magnitude coherence as in (5): Condition #1 & factor EEG14. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

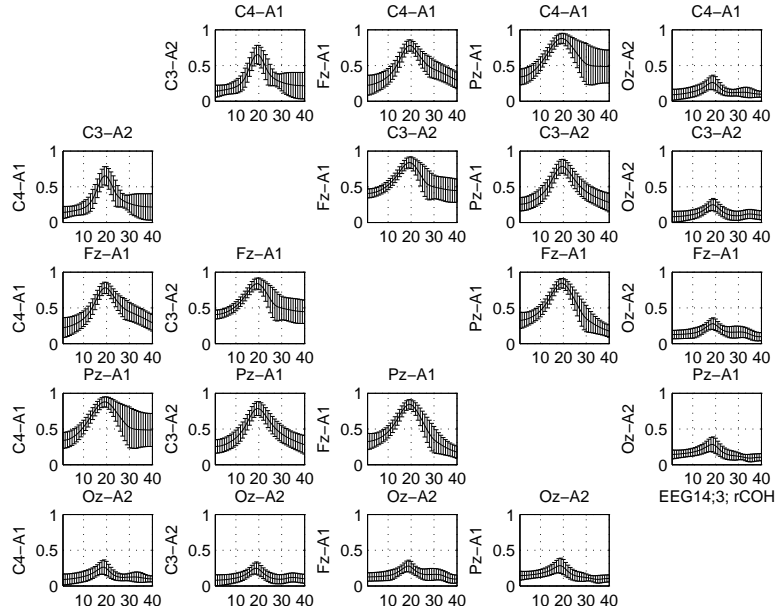


Figure 14: Magnitude coherence as in (5): Condition #3 & factor EEG14. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

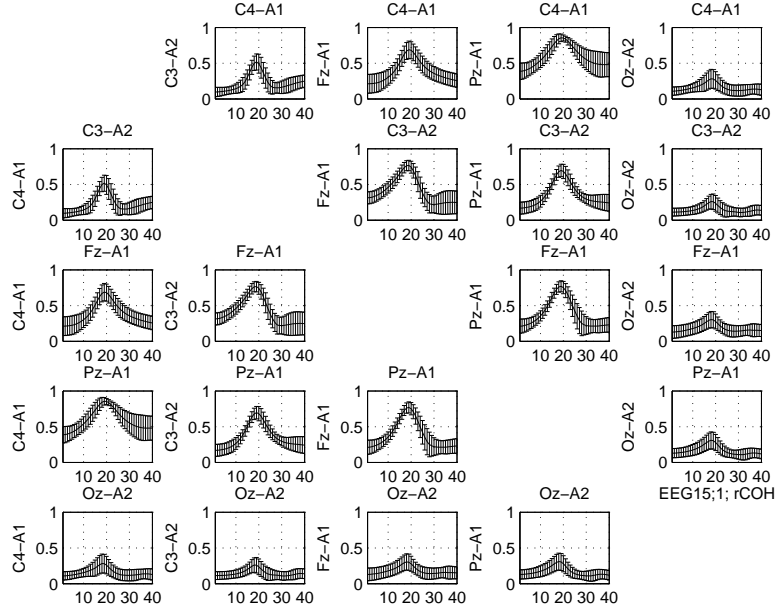


Figure 15: Magnitude coherence as in (5): Condition #1 & factor EEG15. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

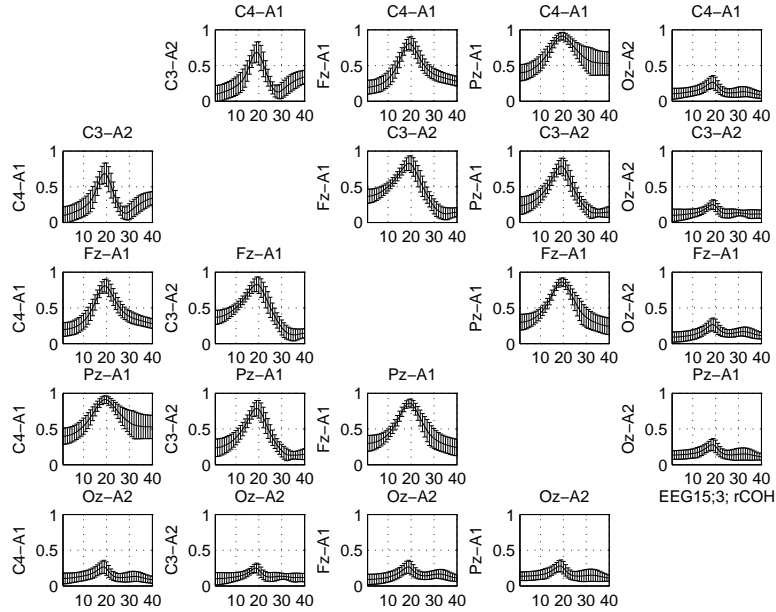


Figure 16: Magnitude coherence as in (5): Condition #3 & factor EEG15. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

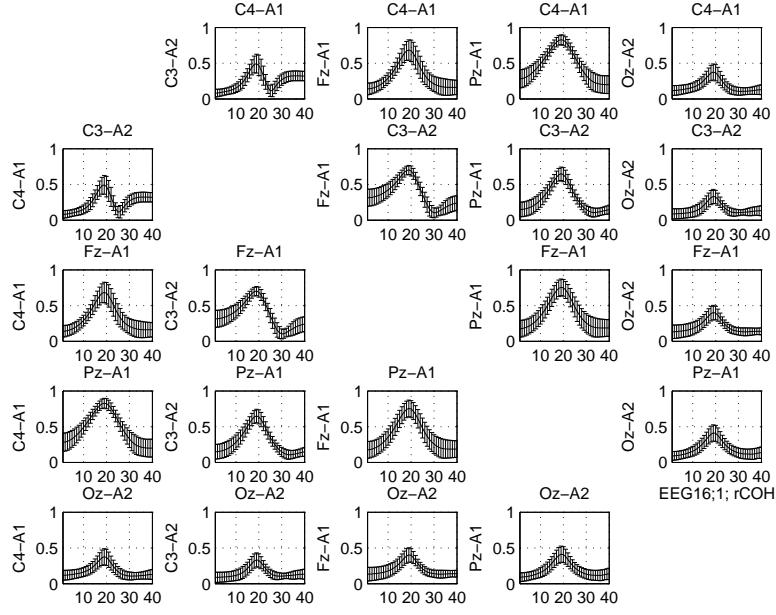


Figure 17: Magnitude coherence as in (5): Condition #1 & factor EEG16. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

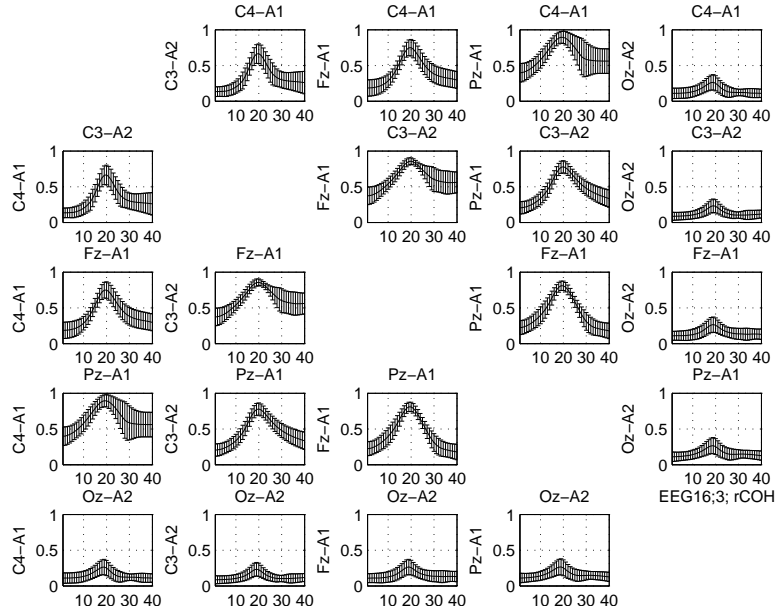


Figure 18: Magnitude coherence as in (5): Condition #3 & factor EEG16. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

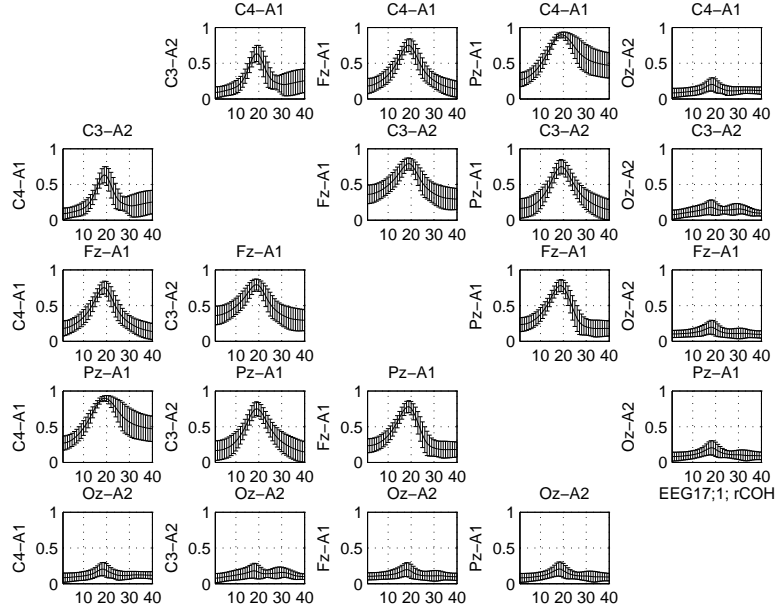


Figure 19: Magnitude coherence as in (5): Condition #1 & factor EEG17. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

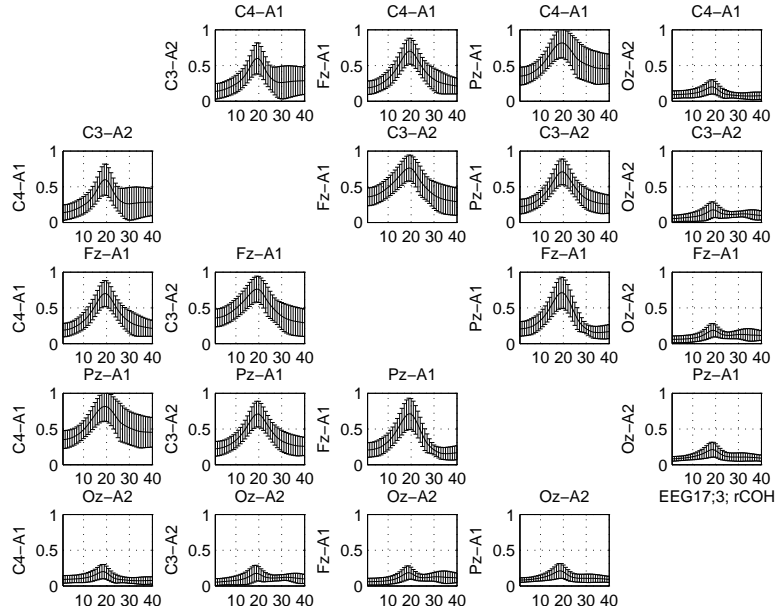


Figure 20: Magnitude coherence as in (5): Condition #3 & factor EEG17. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

3.2 Phase coherence

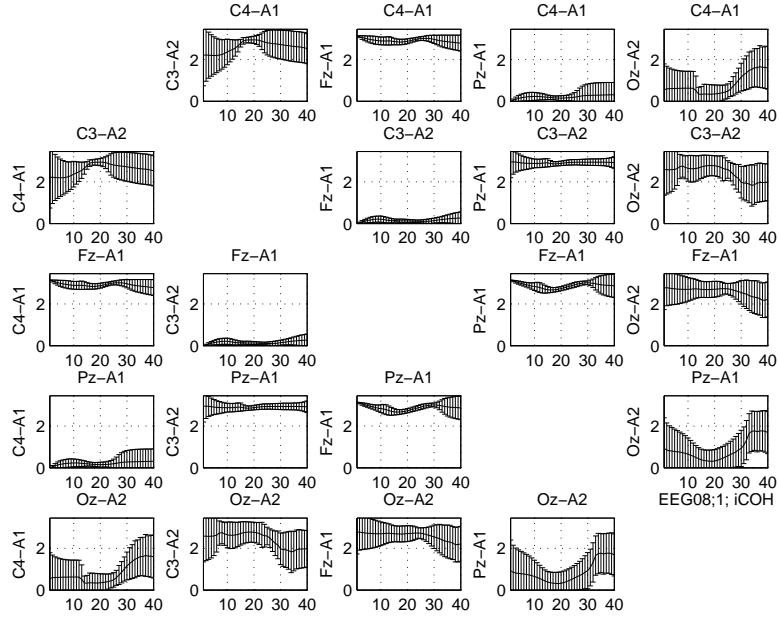


Figure 21: Phase coherence as in (6): Condition #1 & factor EEG08. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

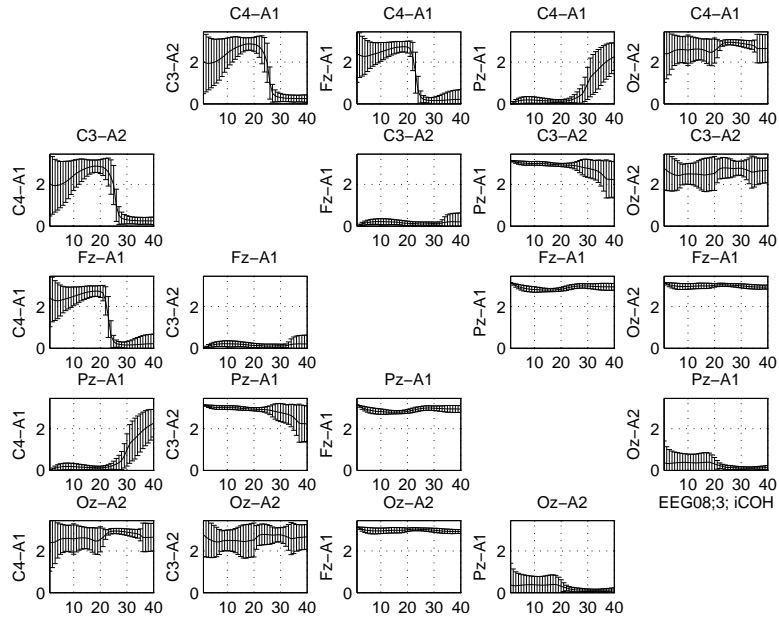


Figure 22: Phase coherence as in (6): Condition #3 & factor EEG08. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

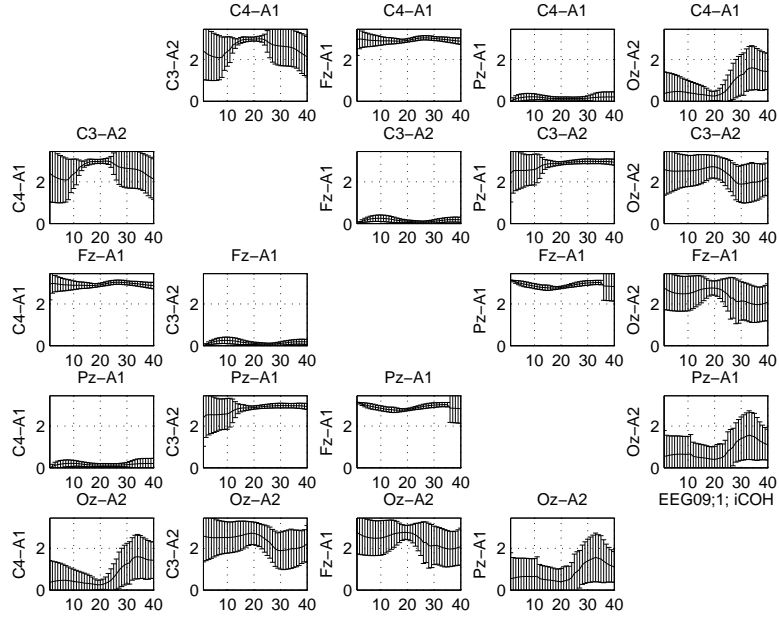


Figure 23: Phase coherence as in (6): Condition #1 & factor EEG09. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

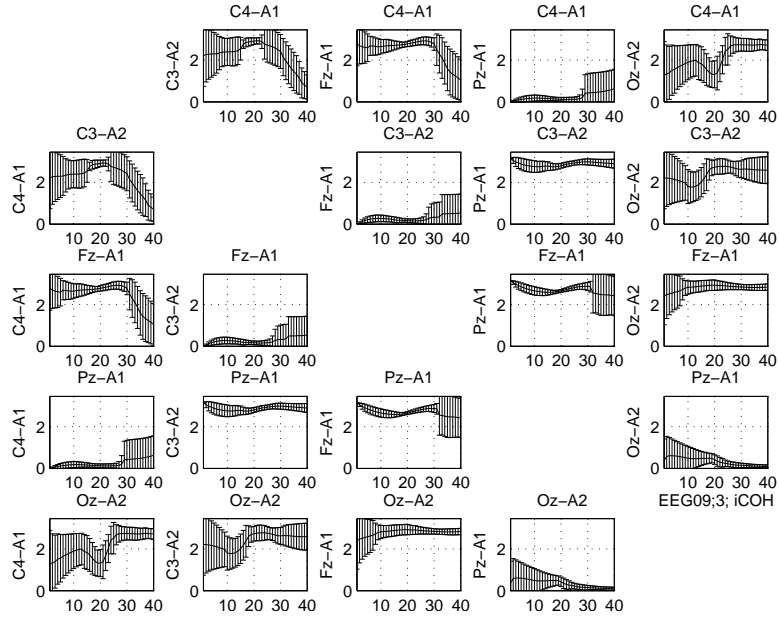


Figure 24: Phase coherence as in (6): Condition #3 & factor EEG09. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

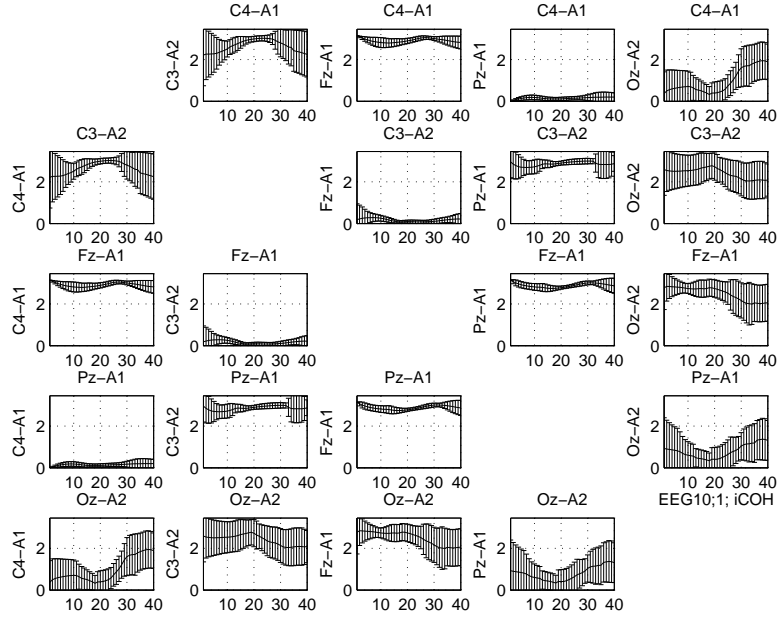


Figure 25: Phase coherence as in (6): Condition #1 & factor EEG10. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

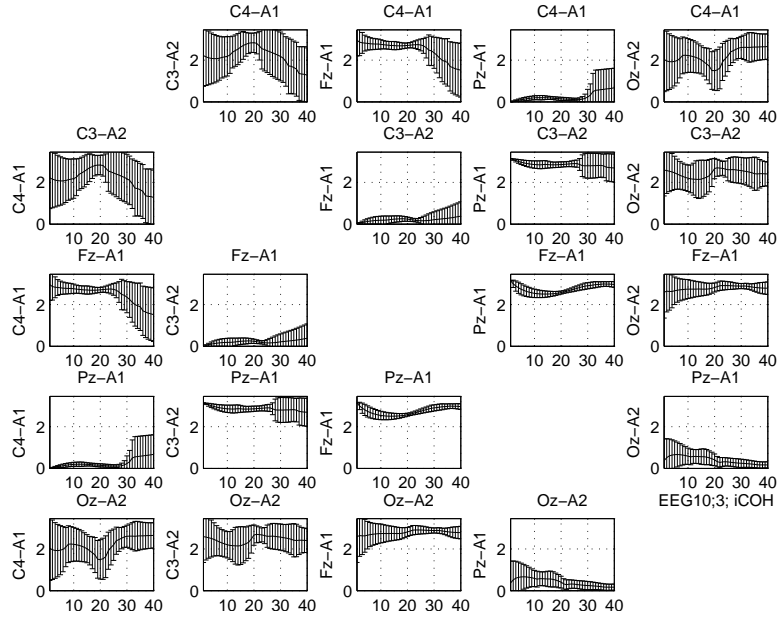


Figure 26: Phase coherence as in (6): Condition #3 & factor EEG10. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

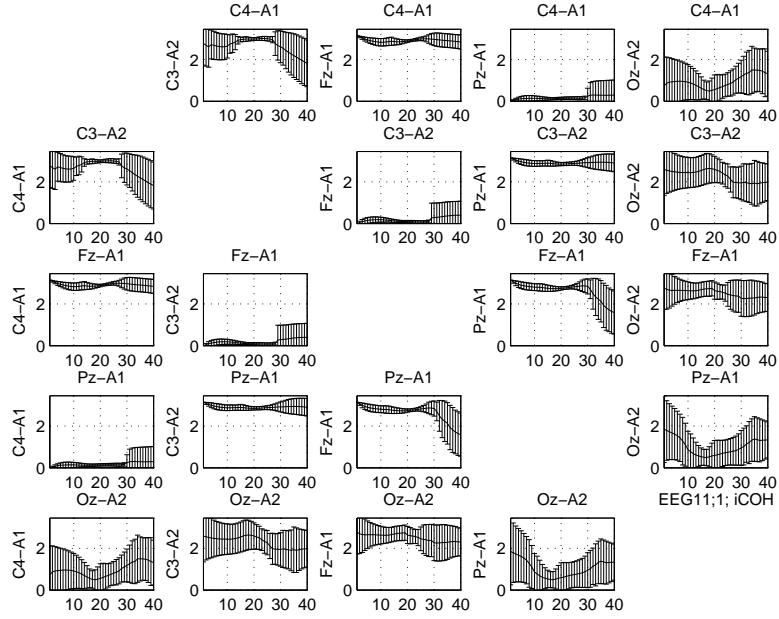


Figure 27: Phase coherence as in (6): Condition #1 & factor EEG11. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

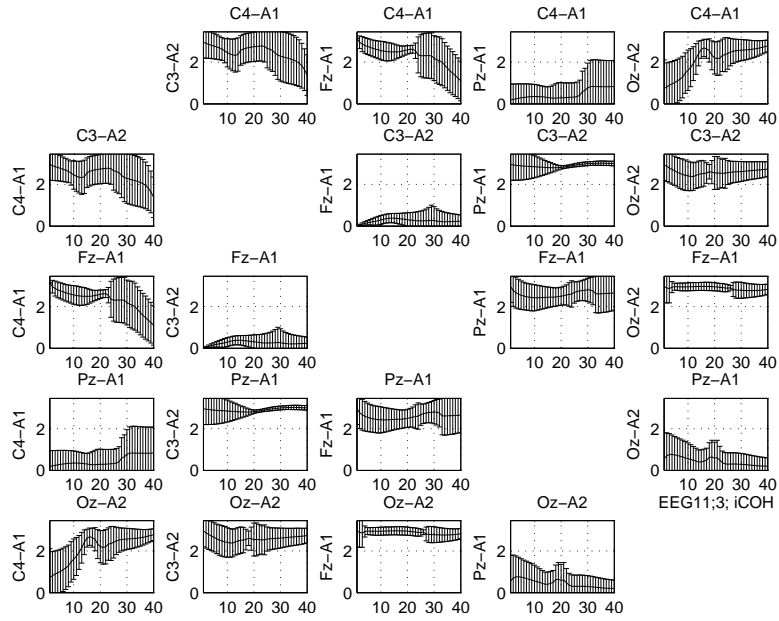


Figure 28: Phase coherence as in (6): Condition #3 & factor EEG11. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

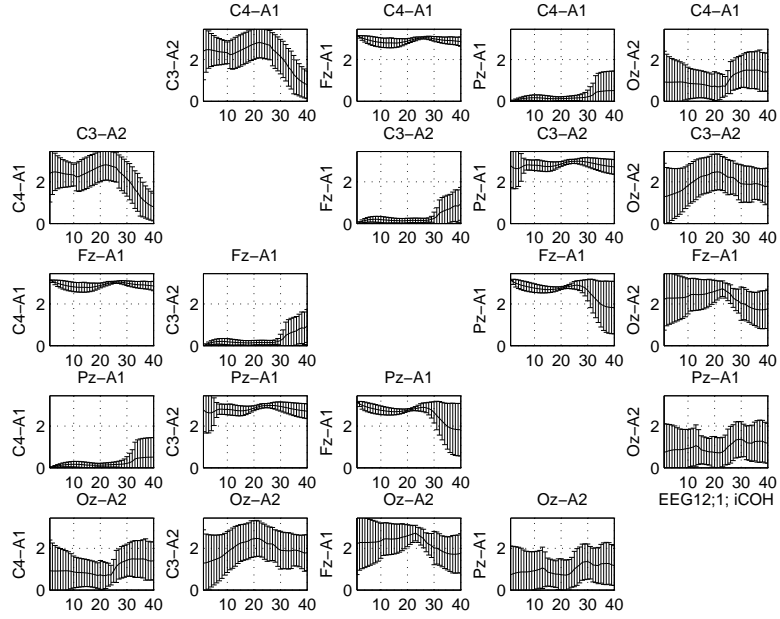


Figure 29: Phase coherence as in (6): Condition #1 & factor EEG12. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

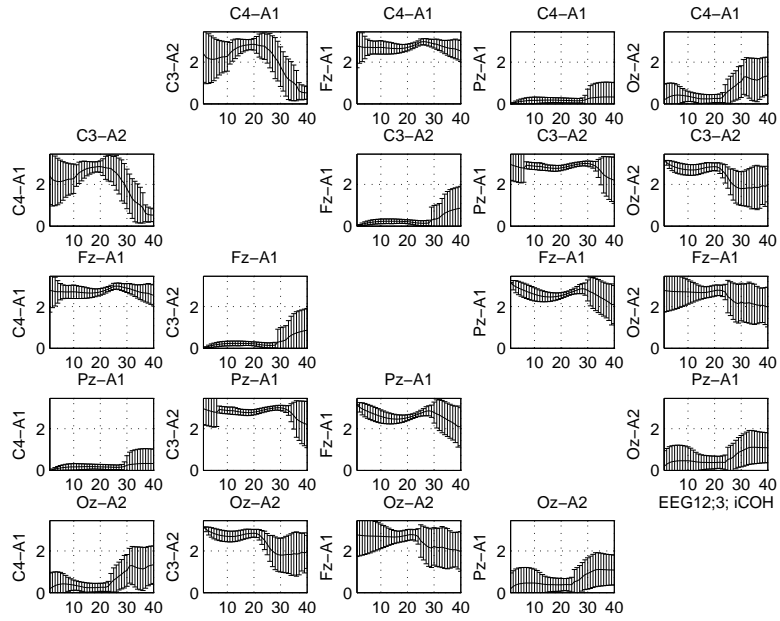


Figure 30: Phase coherence as in (6): Condition #3 & factor EEG12. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

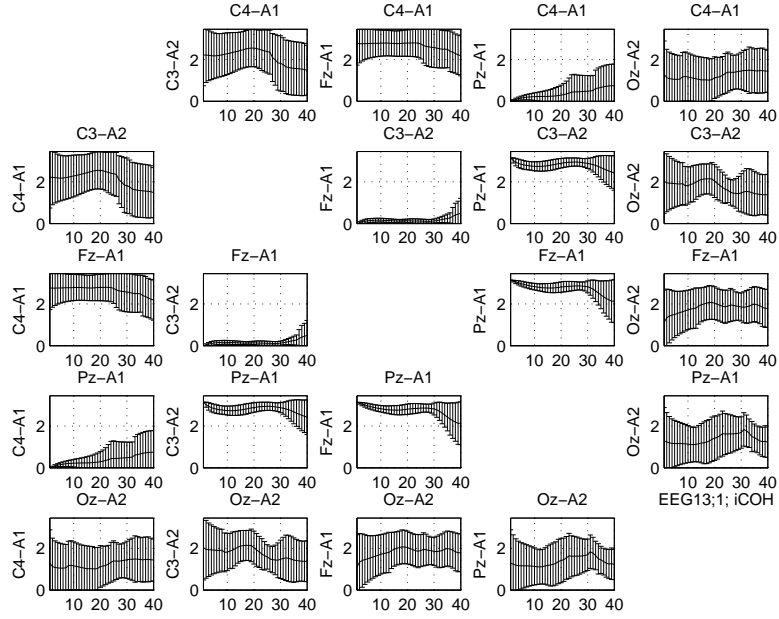


Figure 31: Phase coherence as in (6): Condition #1 & factor EEG13. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

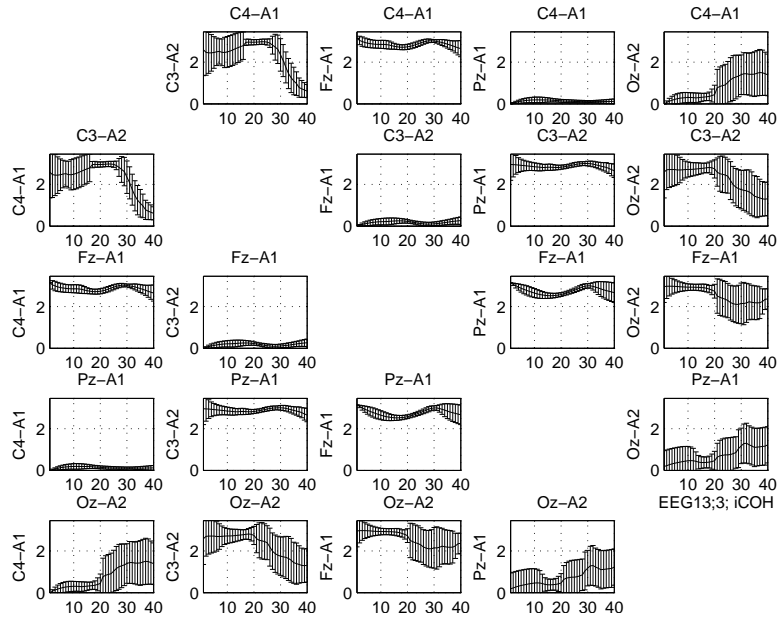


Figure 32: Phase coherence as in (6): Condition #3 & factor EEG13. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

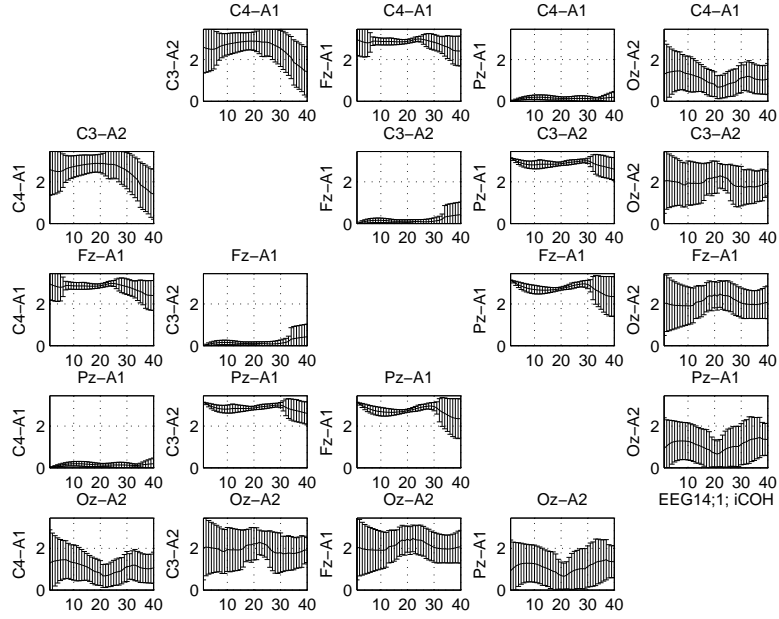


Figure 33: Phase coherence as in (6): Condition #1 & factor EEG14. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

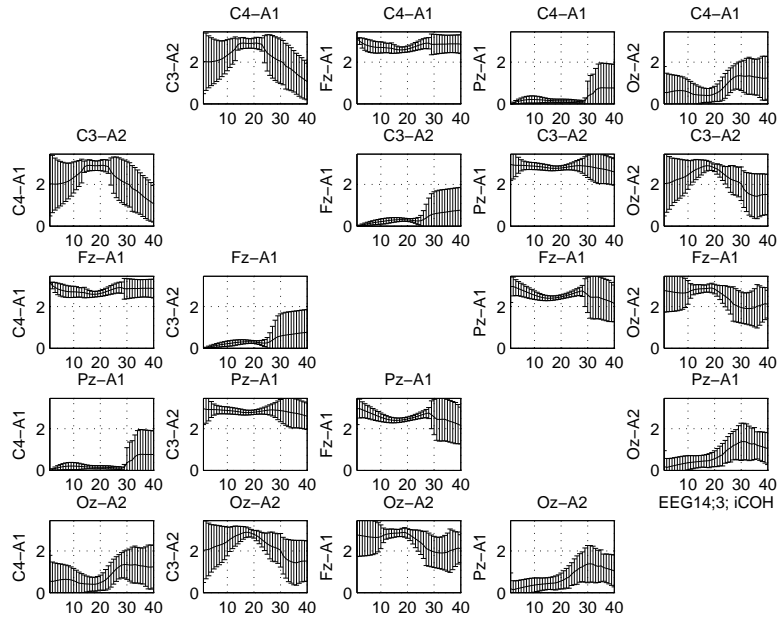


Figure 34: Phase coherence as in (6): Condition #3 & factor EEG14. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

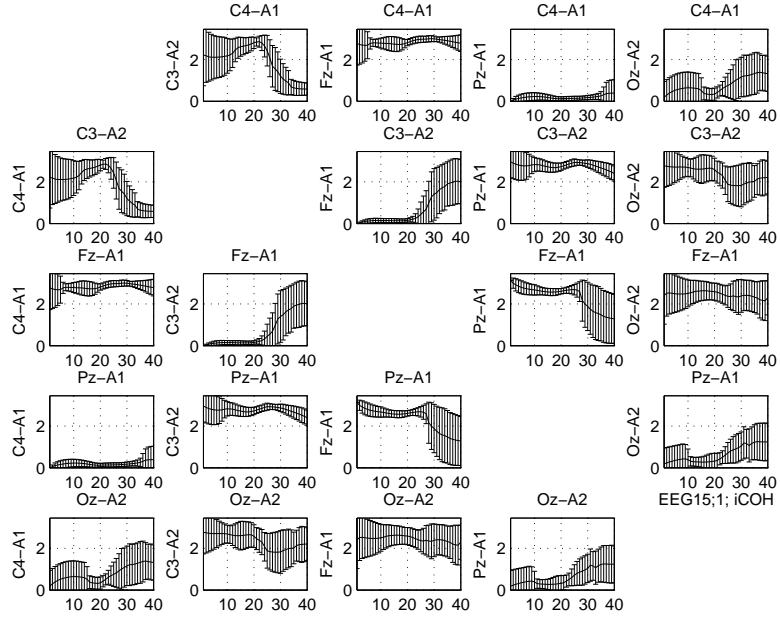


Figure 35: Phase coherence as in (6): Condition #1 & factor EEG15. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

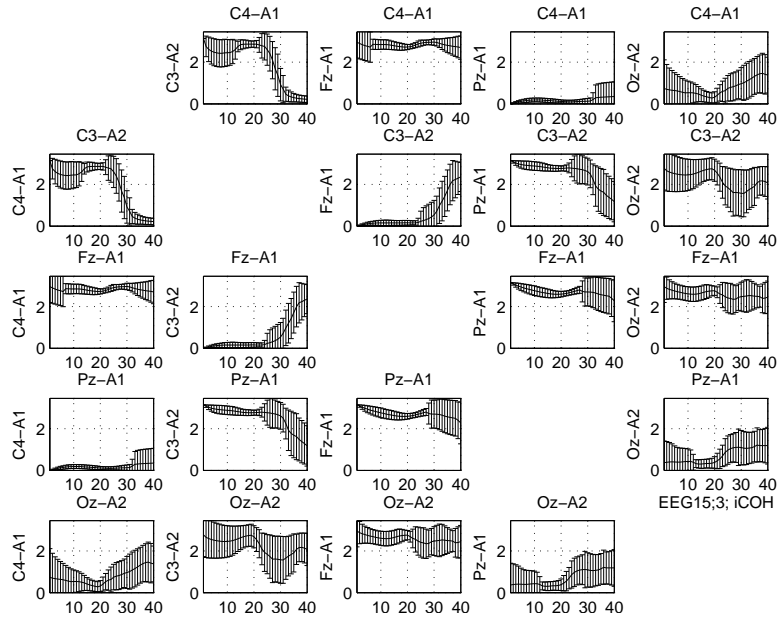


Figure 36: Phase coherence as in (6): Condition #3 & factor EEG15. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

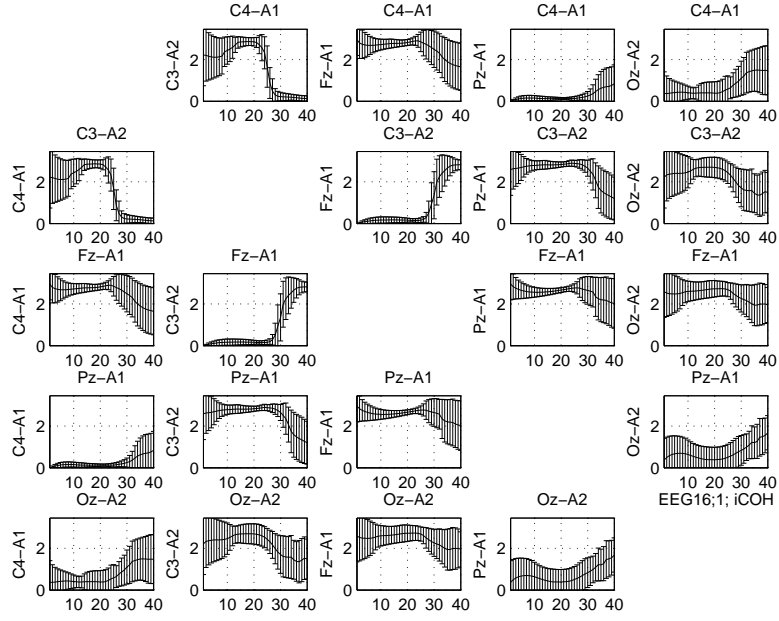


Figure 37: Phase coherence as in (6): Condition #1 & factor EEG16. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

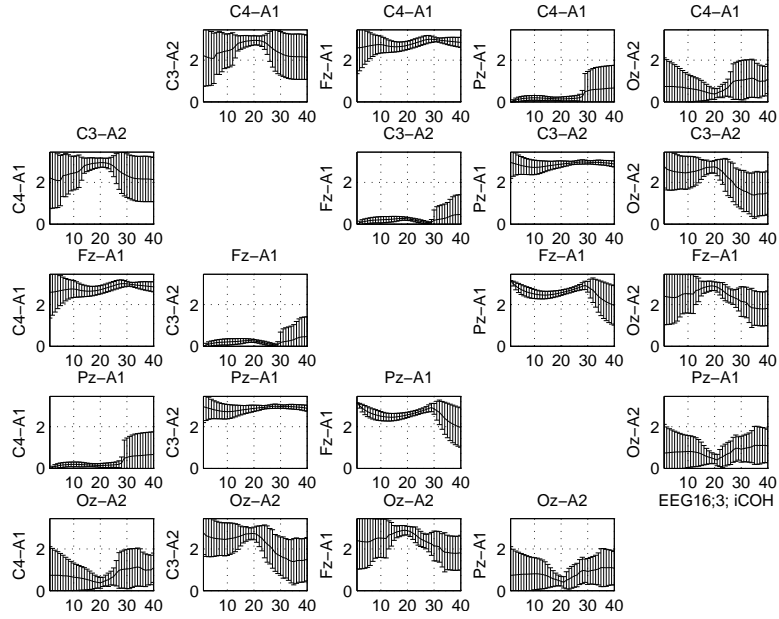


Figure 38: Phase coherence as in (6): Condition #3 & factor EEG16. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

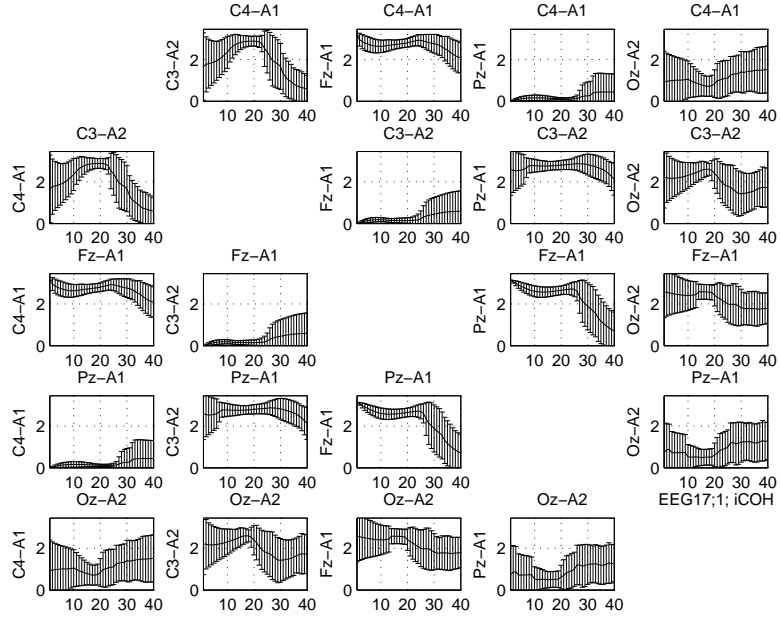


Figure 39: Phase coherence as in (6): Condition #1 & factor EEG17. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

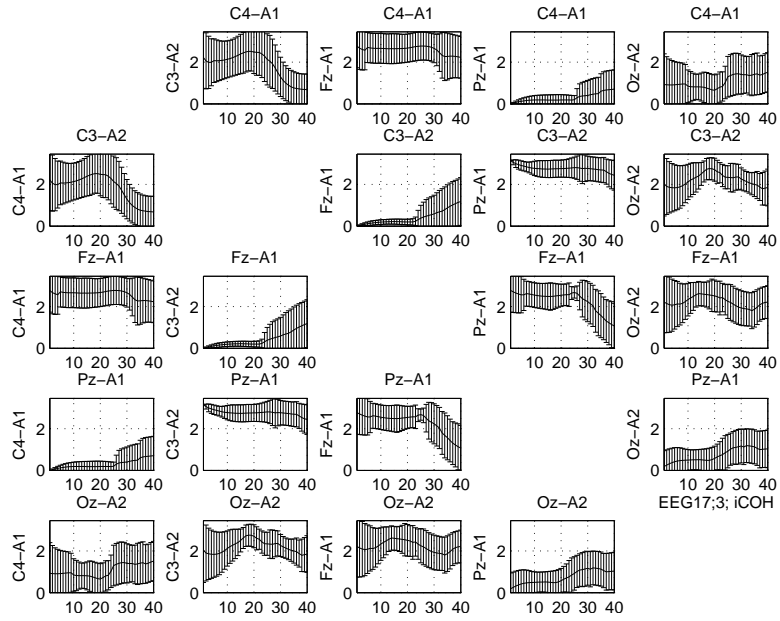


Figure 40: Phase coherence as in (6): Condition #3 & factor EEG17. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

3.3 Directed transfer function (DTF)

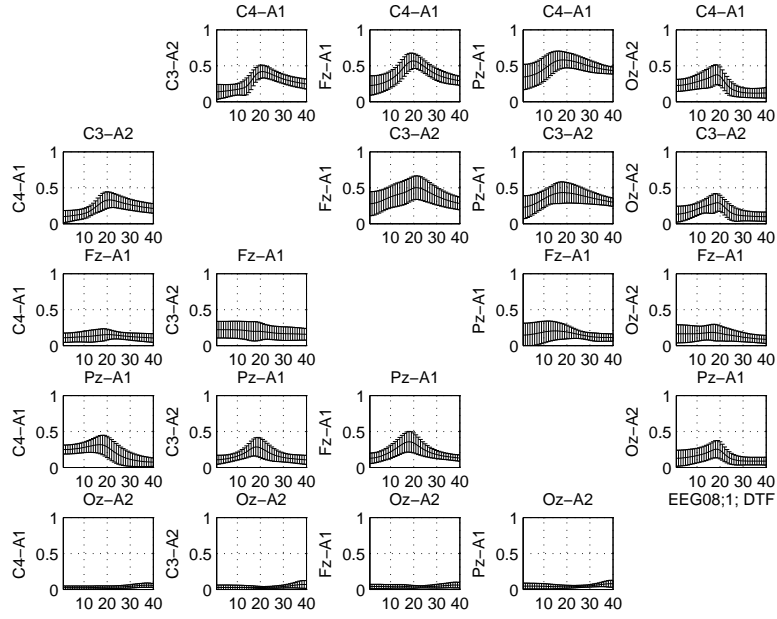


Figure 41: DTF as in (9): Condition #1 and factor EEG08. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

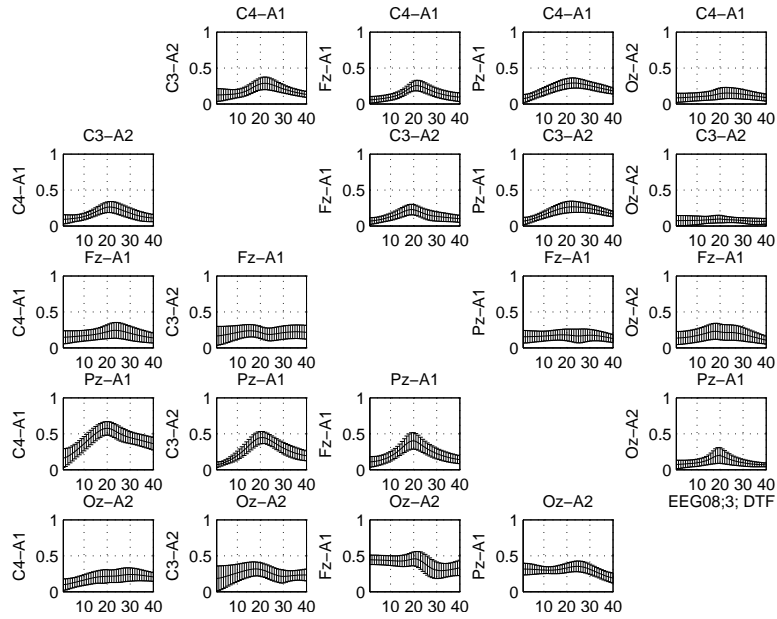


Figure 42: DTF as in (9): Condition #3 and EEG08. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

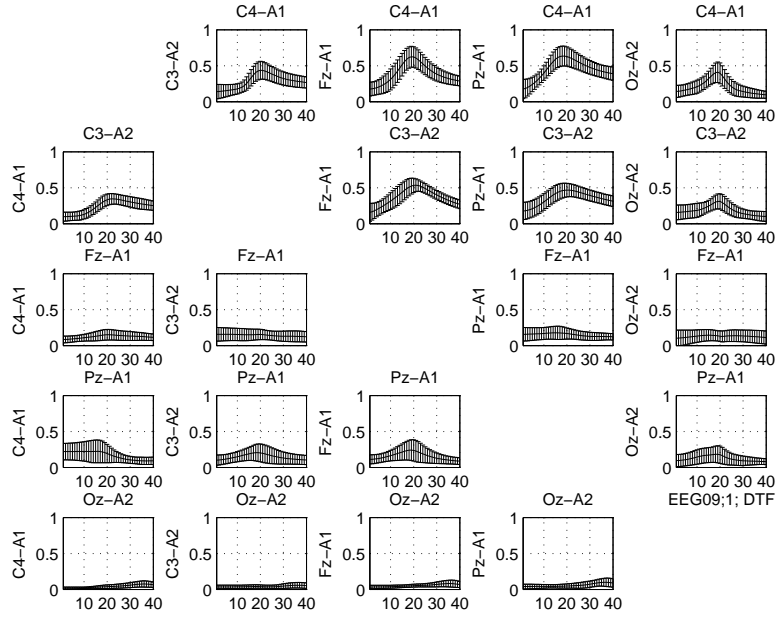


Figure 43: DTF as in (9): Condition #1 and factor EEG09. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

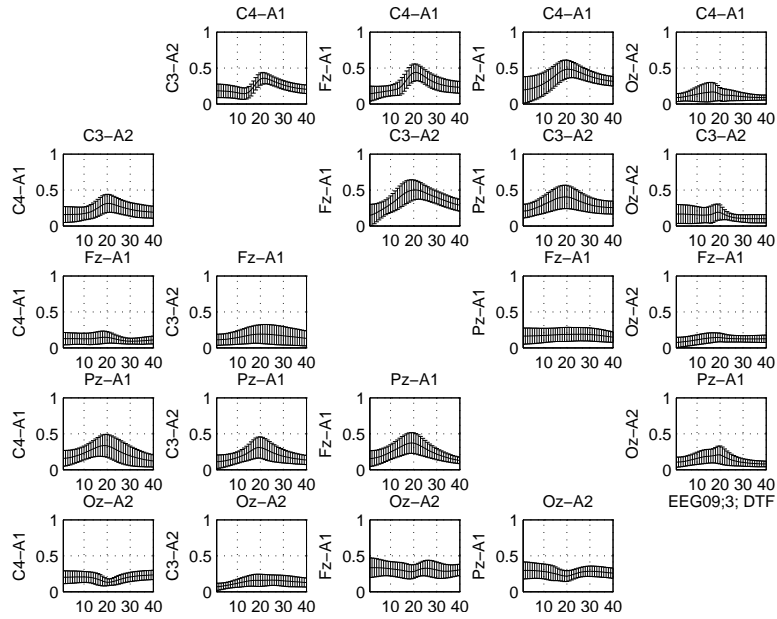


Figure 44: DTF as in (9): Condition #3 and EEG09. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

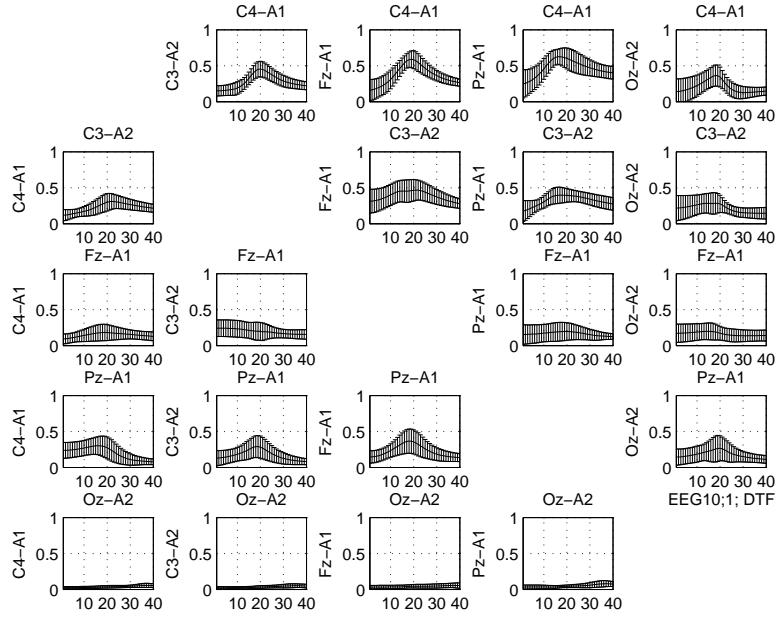


Figure 45: DTF as in (9): Condition #1 and factor EEG10. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

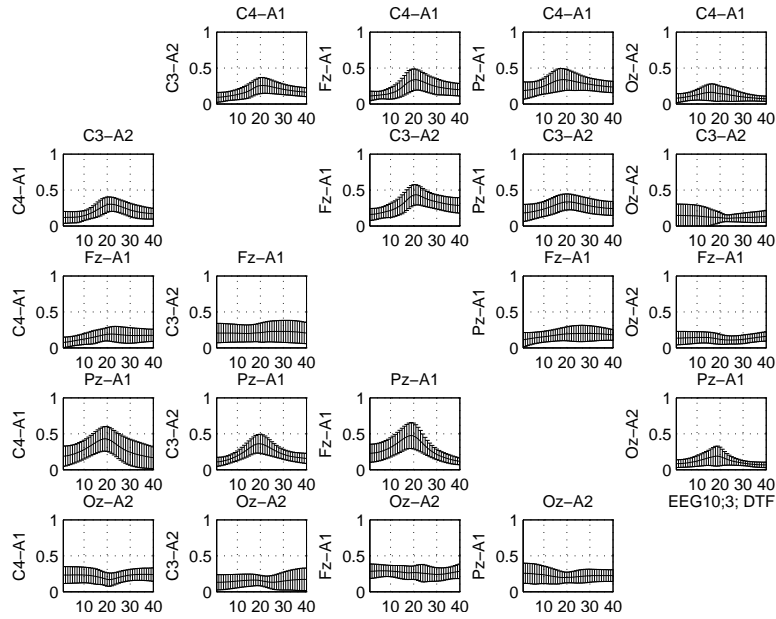


Figure 46: DTF as in (9): Condition #3 and EEG10. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

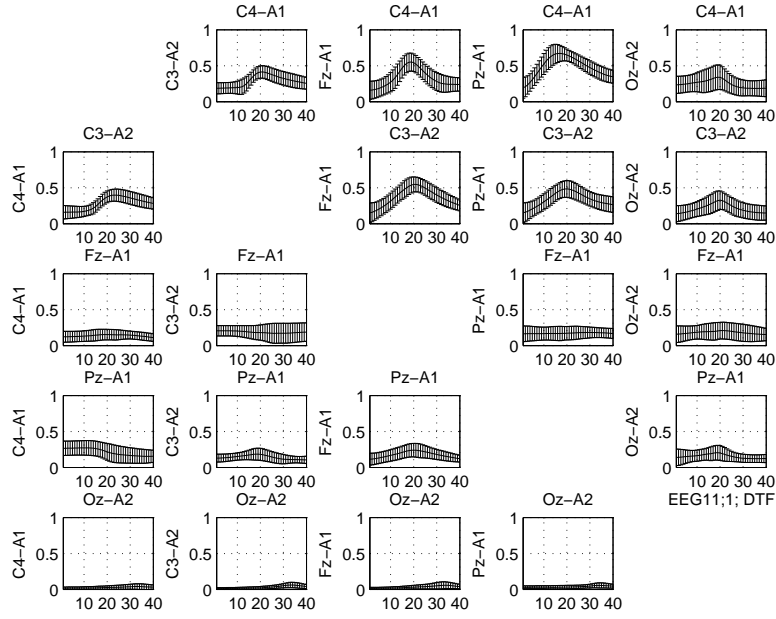


Figure 47: DTF as in (9): Condition #1 and factor EEG11. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

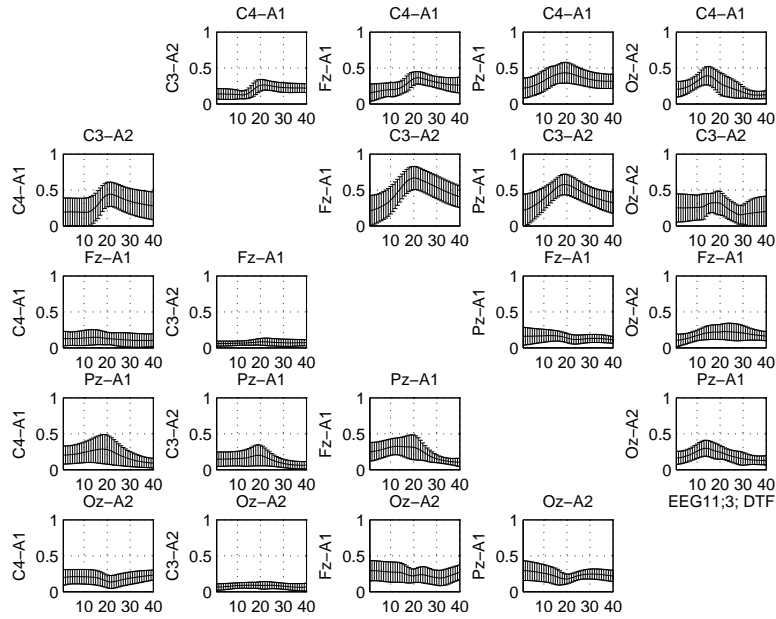


Figure 48: DTF as in (9): Condition #3 and EEG11. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

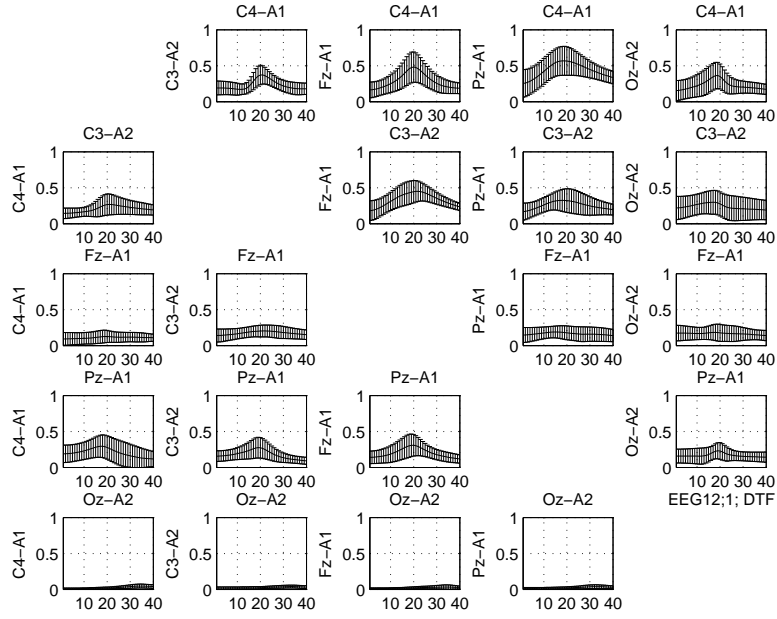


Figure 49: DTF as in (9): Condition #1 and factor EEG12. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

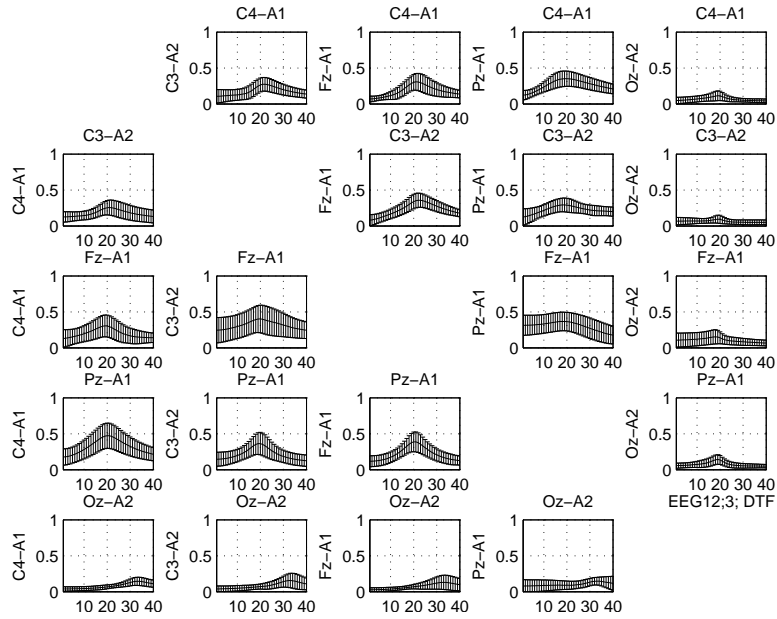


Figure 50: DTF as in (9): Condition #3 and EEG12. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

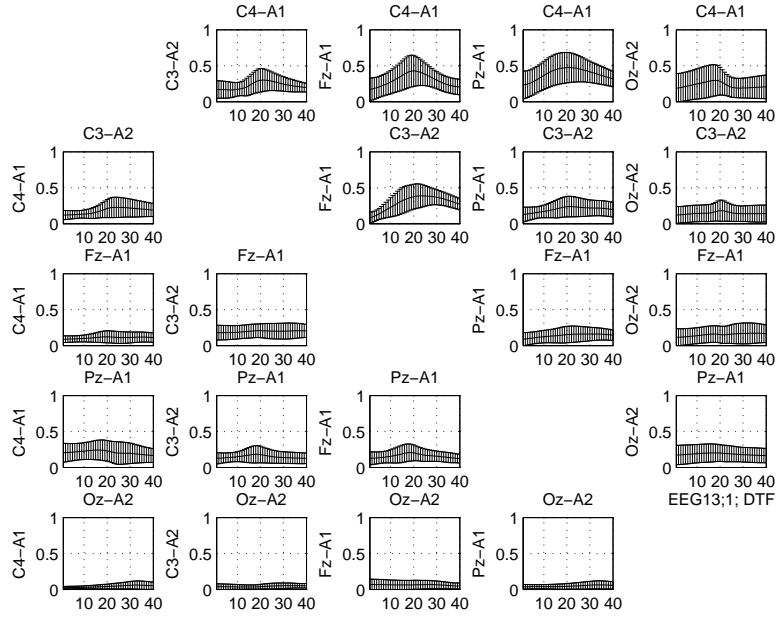


Figure 51: DTF as in (9): Condition #1 and factor EEG13. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

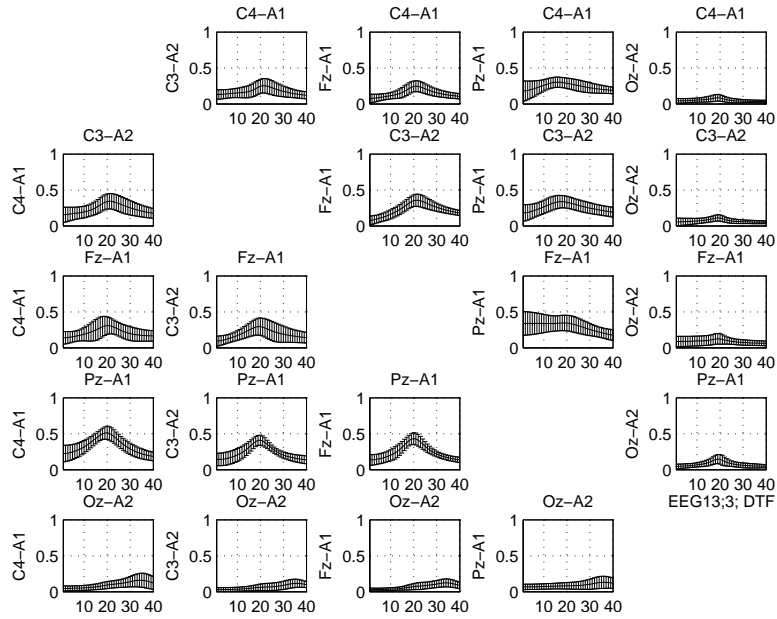


Figure 52: DTF as in (9): Condition #3 and EEG13. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

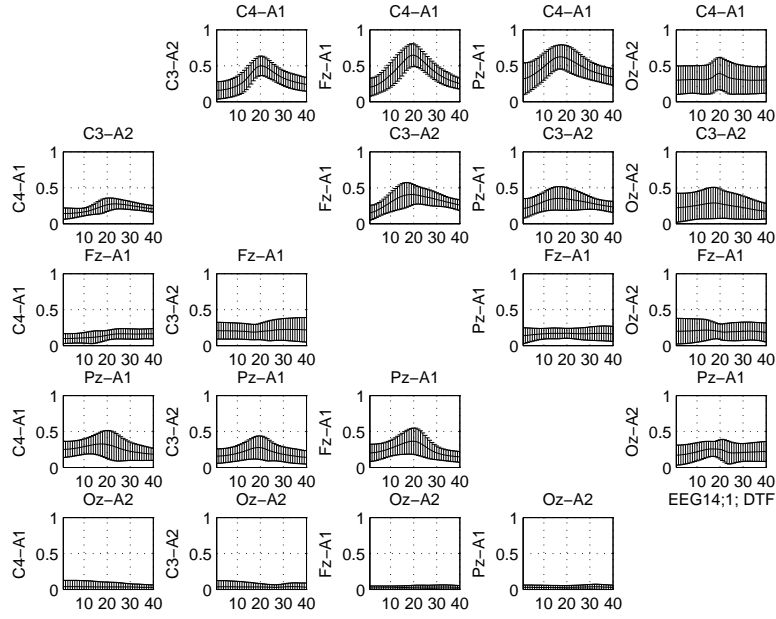


Figure 53: DTF as in (9): Condition #1 and factor EEG14. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

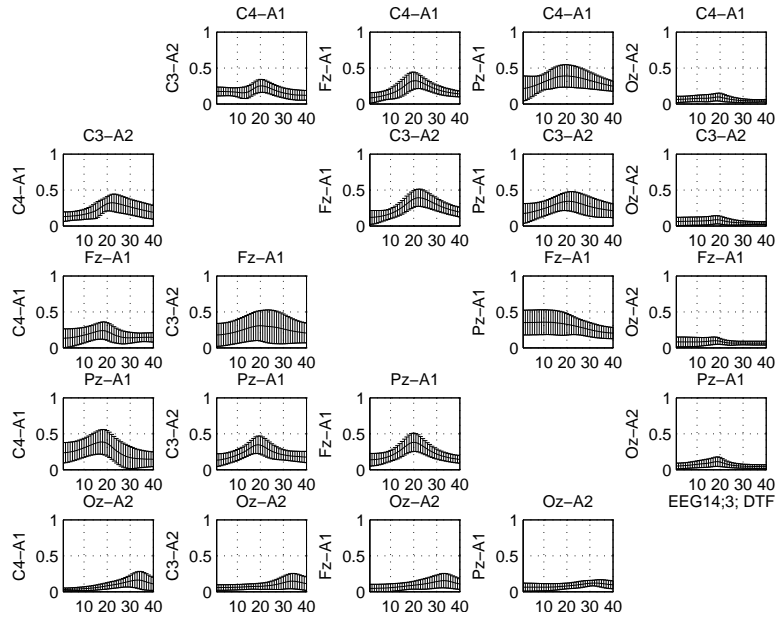


Figure 54: DTF as in (9): Condition #3 and EEG14. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

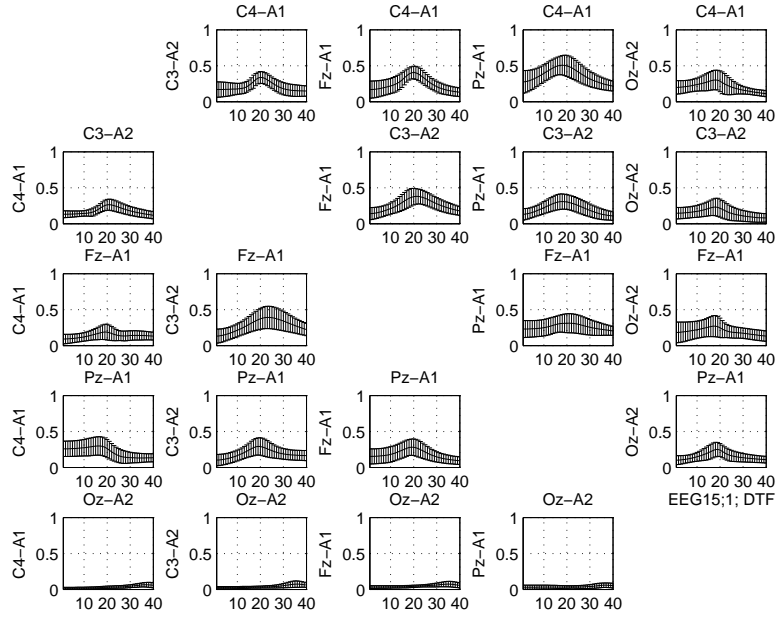


Figure 55: DTF as in (9): Condition #1 and factor EEG15. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

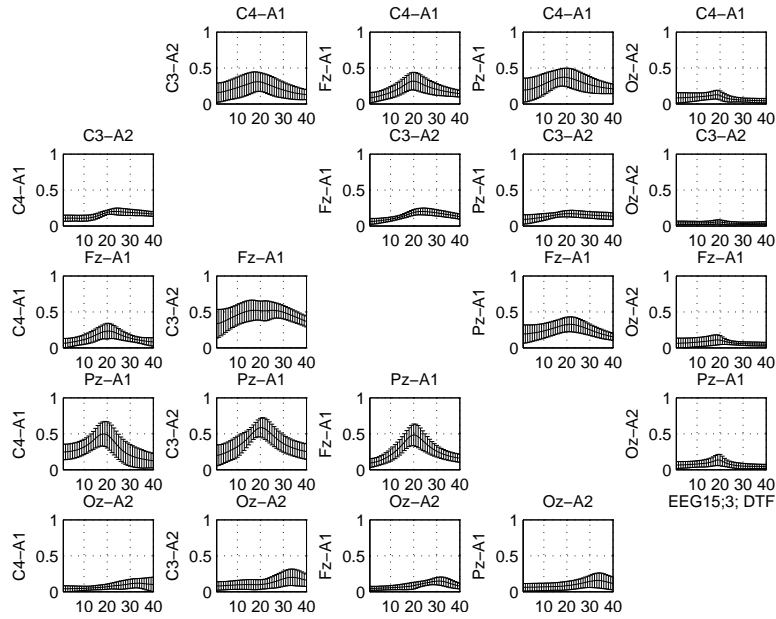


Figure 56: DTF as in (9): Condition #3 and EEG15. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

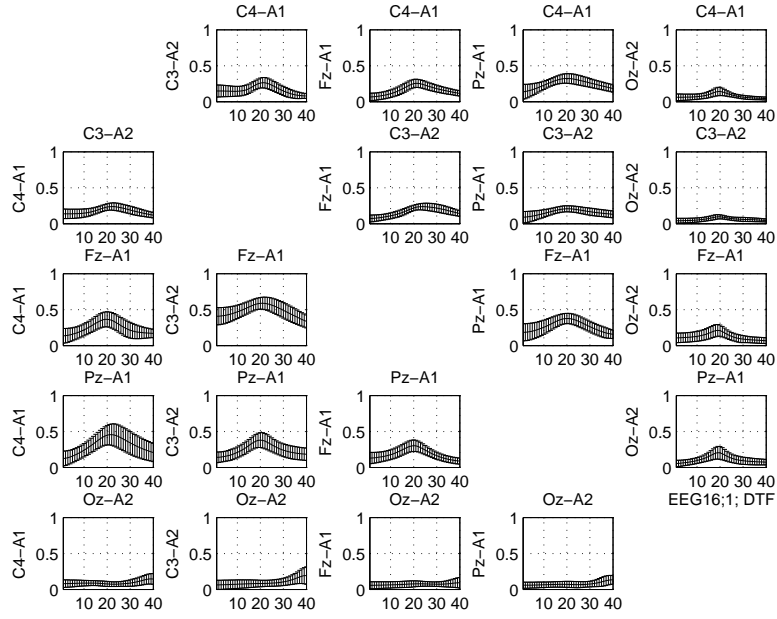


Figure 57: DTF as in (9): Condition #1 and factor EEG16. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

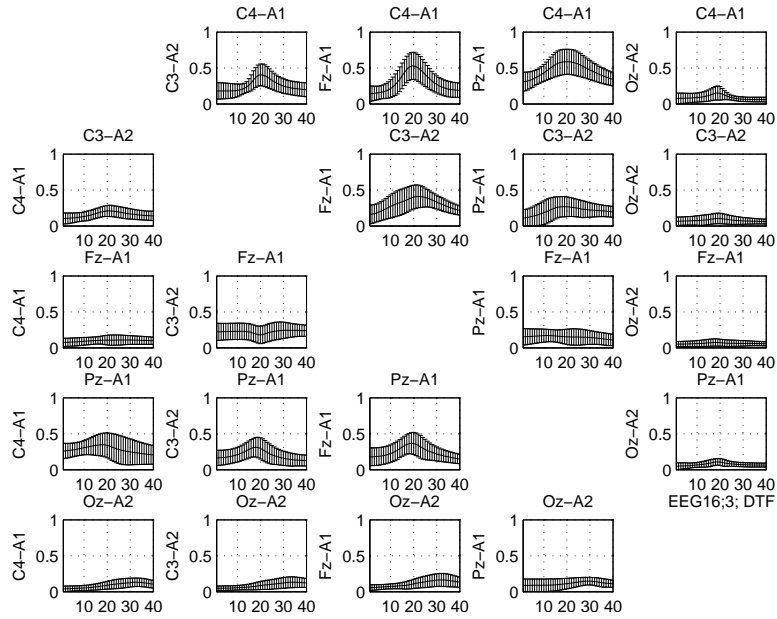


Figure 58: DTF as in (9): Condition #3 and EEG16. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

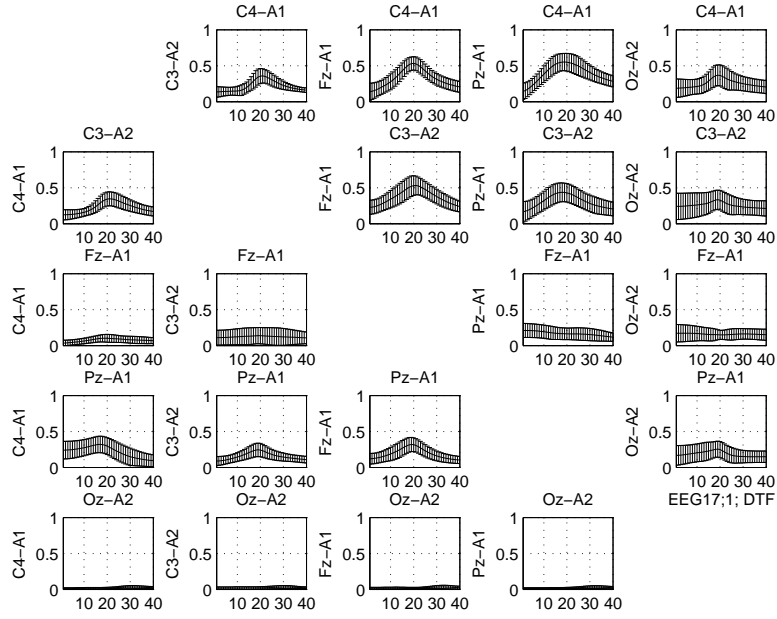


Figure 59: DTF as in (9): Condition #1 and factor EEG17. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

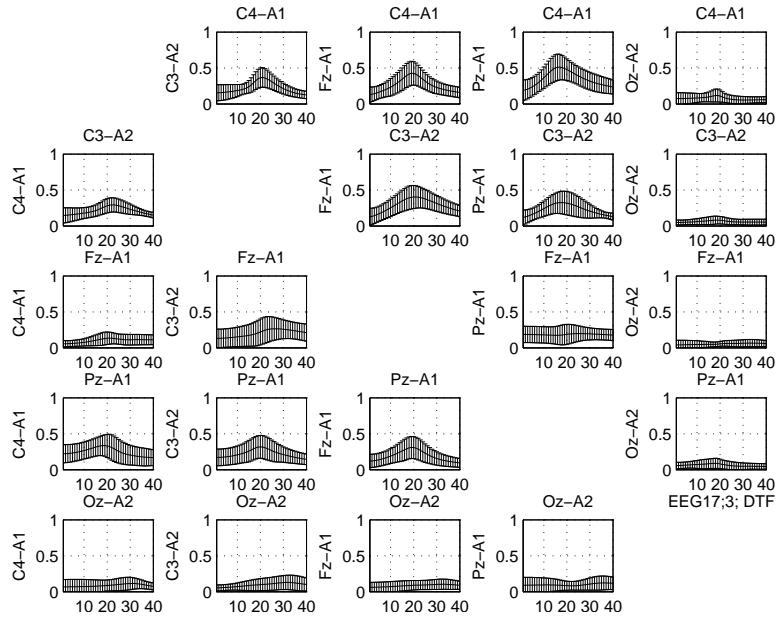


Figure 60: DTF as in (9): Condition #3 and EEG17. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

3.4 Direct directed transfer function (dDTF)

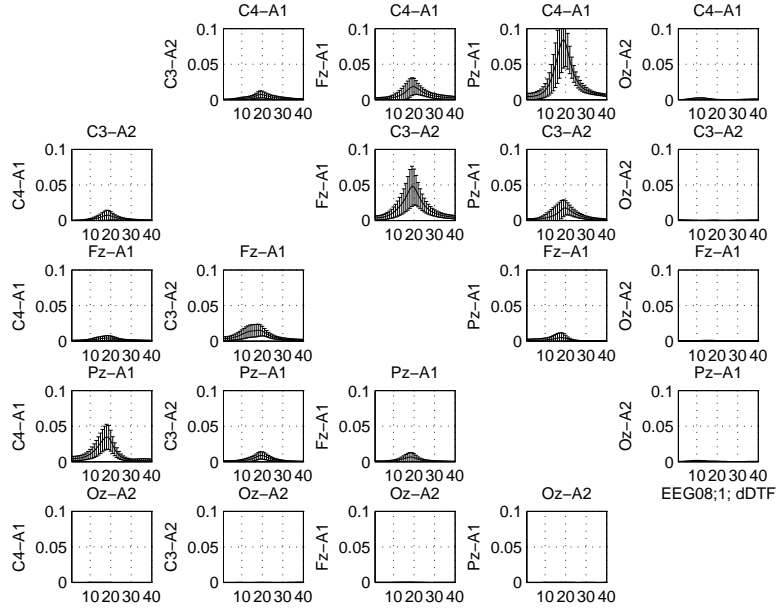


Figure 61: dDTF as in (11): as in (9): Condition #1 and EEG08. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

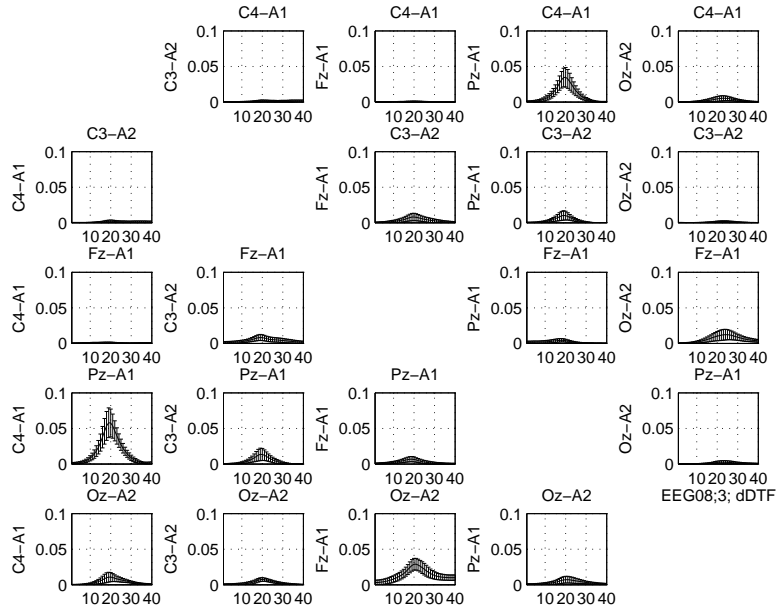


Figure 62: dDTF as in (11): Condition #3 and EEG08. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

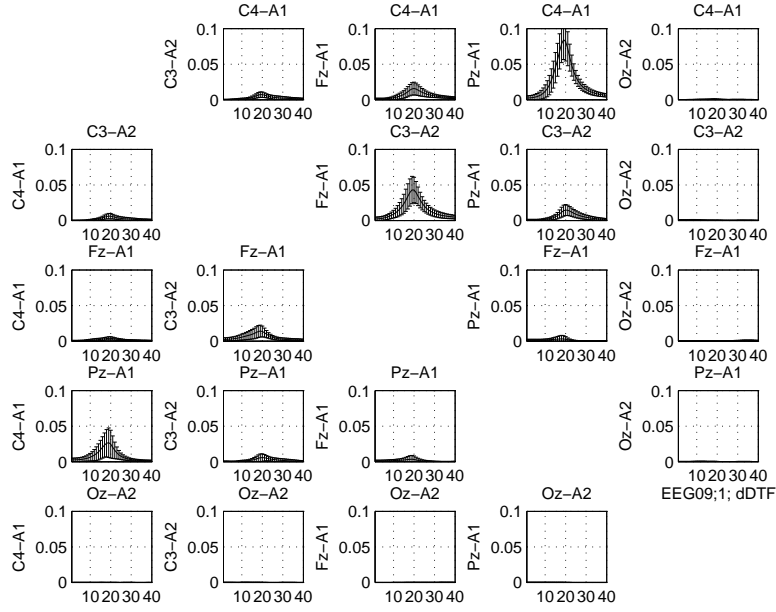


Figure 63: dDTF as in (11): Condition #1 and EEG09. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

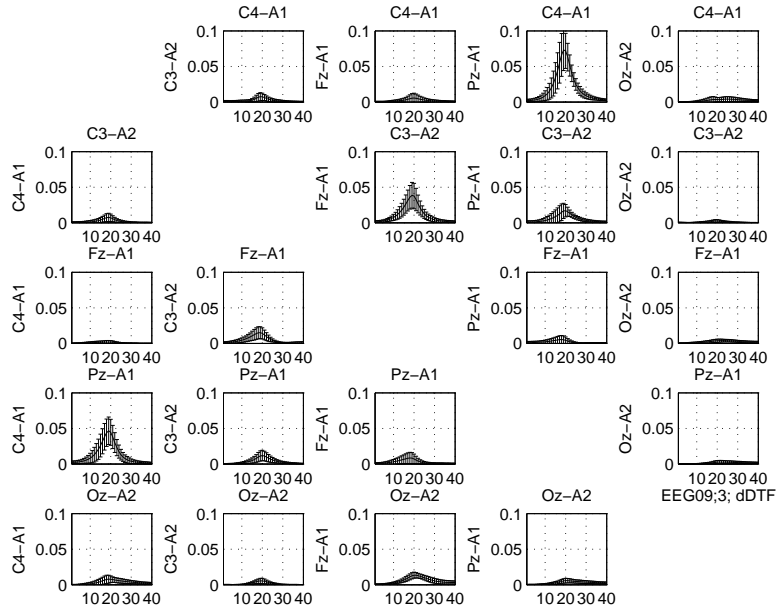


Figure 64: dDTF as in (11): Condition #3 and EEG09. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

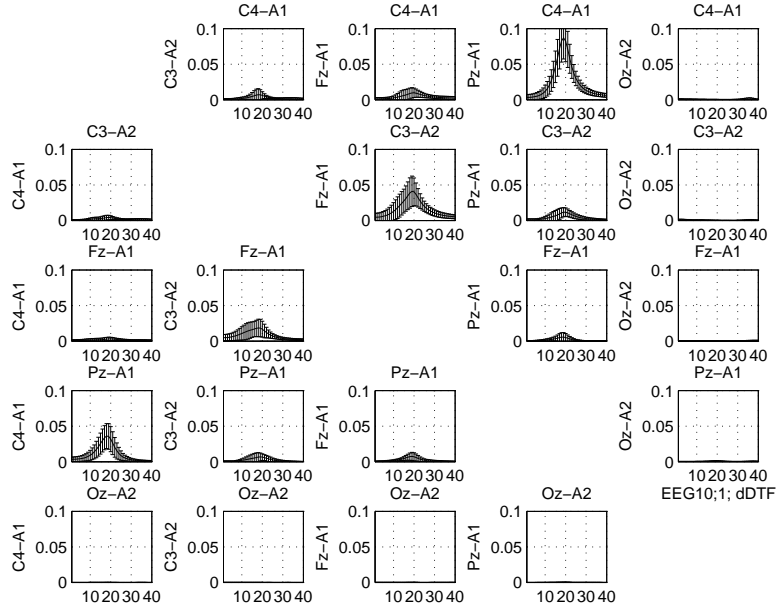


Figure 65: dDTF as in (11): Condition #1 and EEG10.X-axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

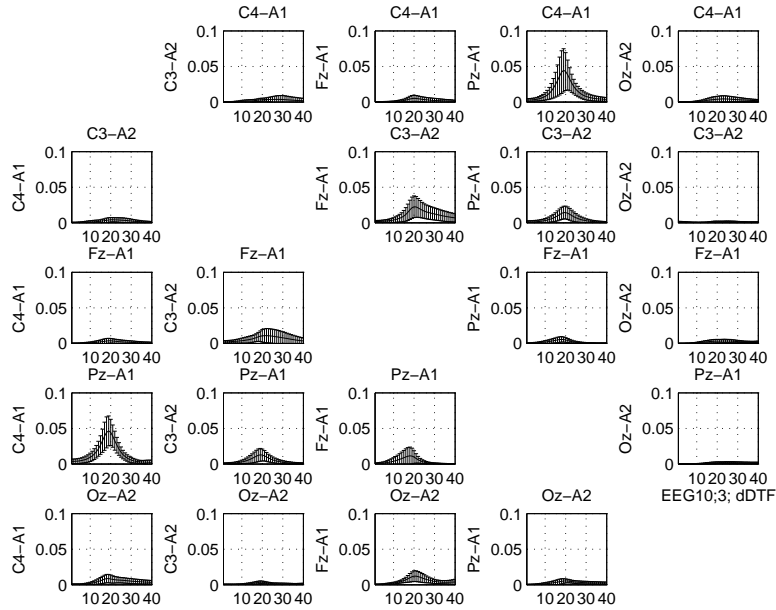


Figure 66: dDTF as in (11): Condition #3 and EEG10.X-axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

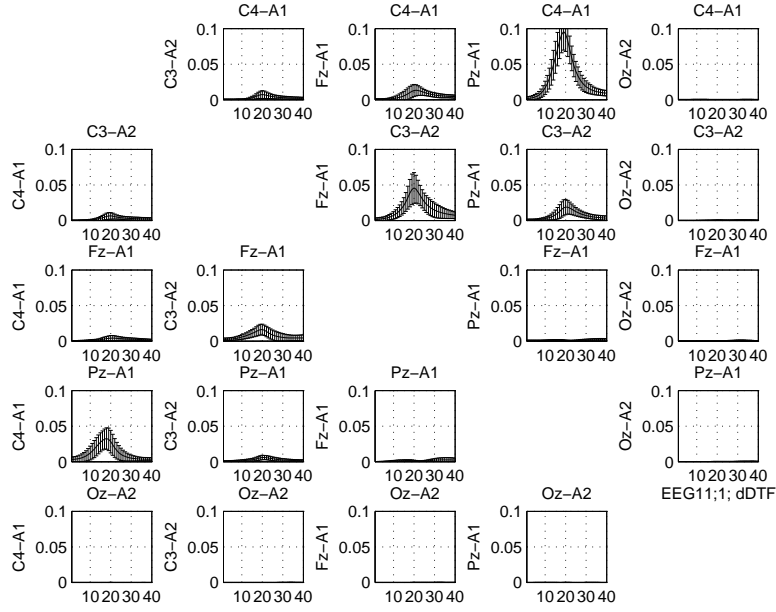


Figure 67: dDTF as in (11): Condition #1 and EEG11.*X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

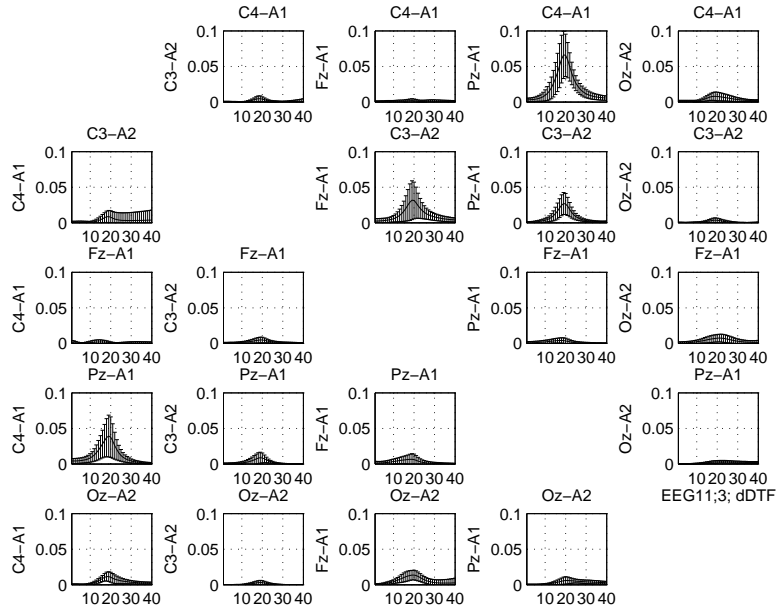


Figure 68: dDTF as in (11): Condition #3 and EEG11.*X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

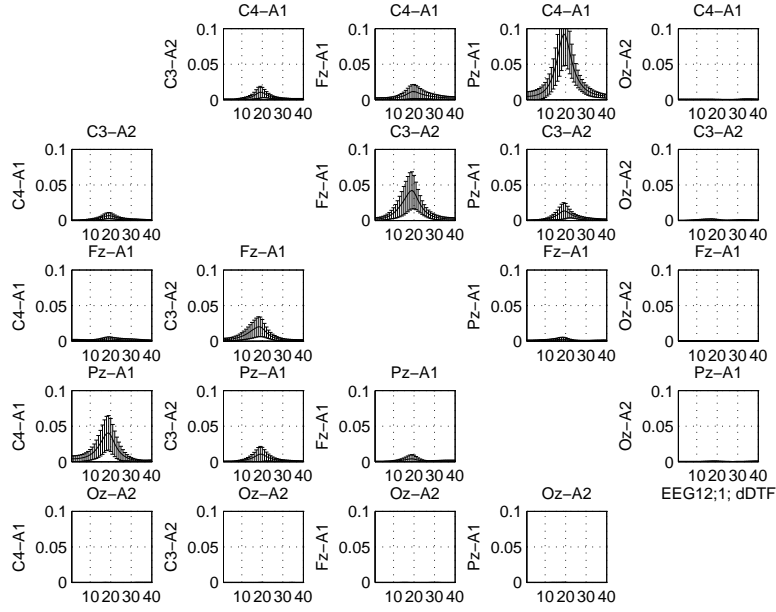


Figure 69: dDTF as in (11): Condition #1 and EEG12. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

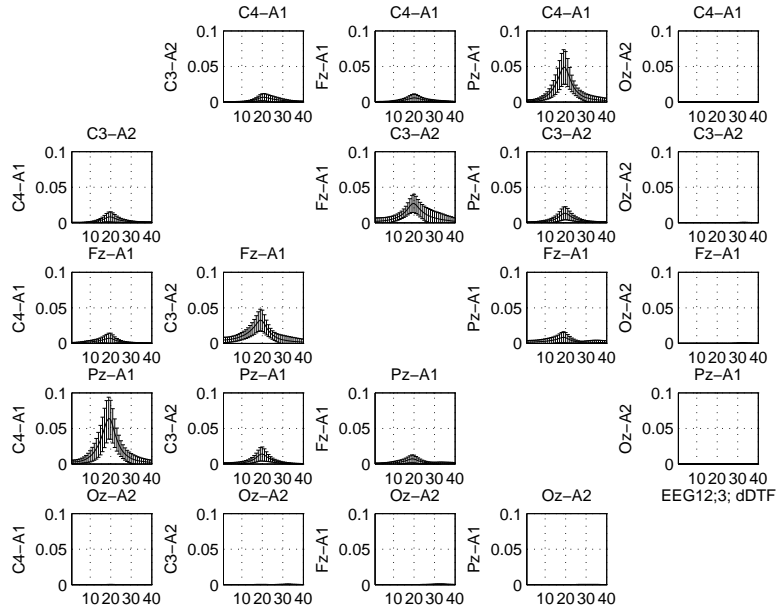


Figure 70: dDTF as in (11): Condition #3 and EEG12. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

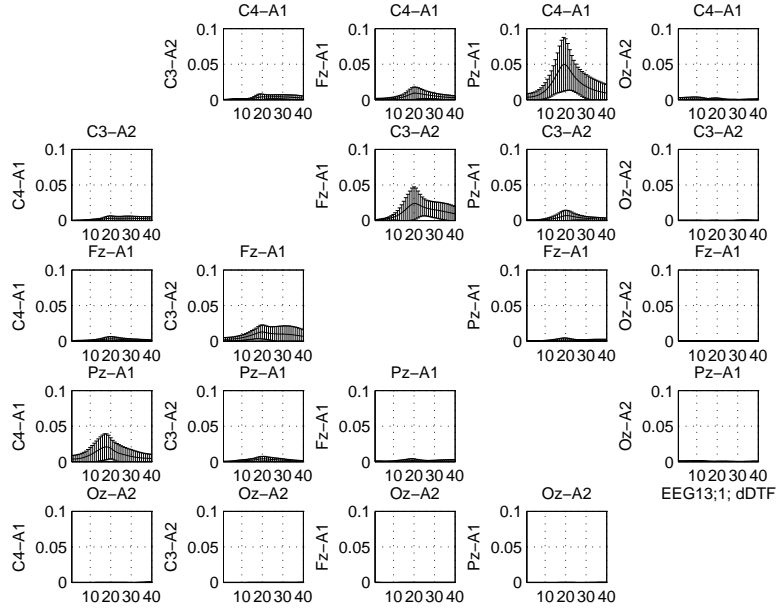


Figure 71: dDTF as in (11): Condition #1 and EEG13. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

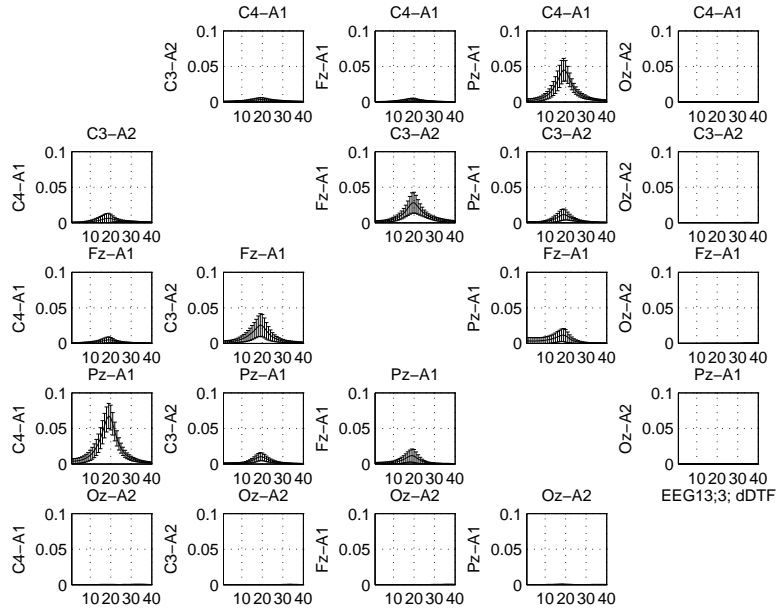


Figure 72: dDTF as in (11): Condition #3 and EEG13. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

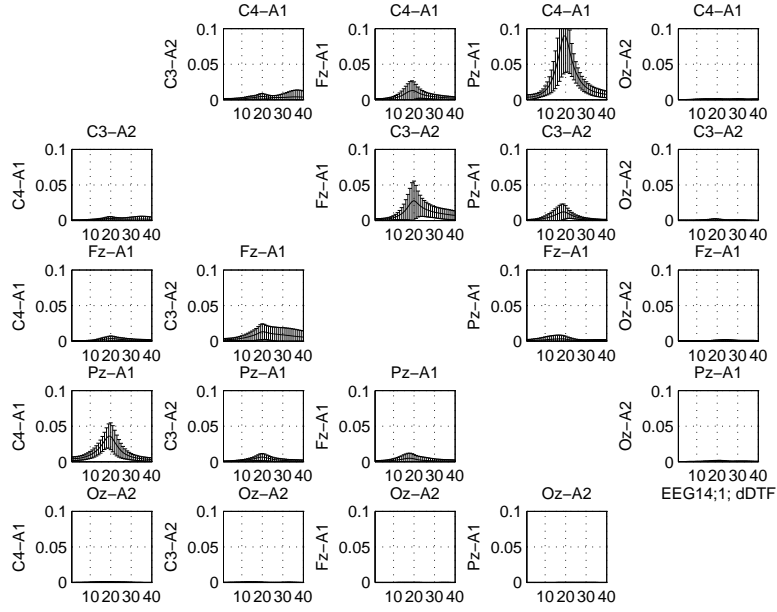


Figure 73: dDTF as in (11): Condition #1 and EEG14. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

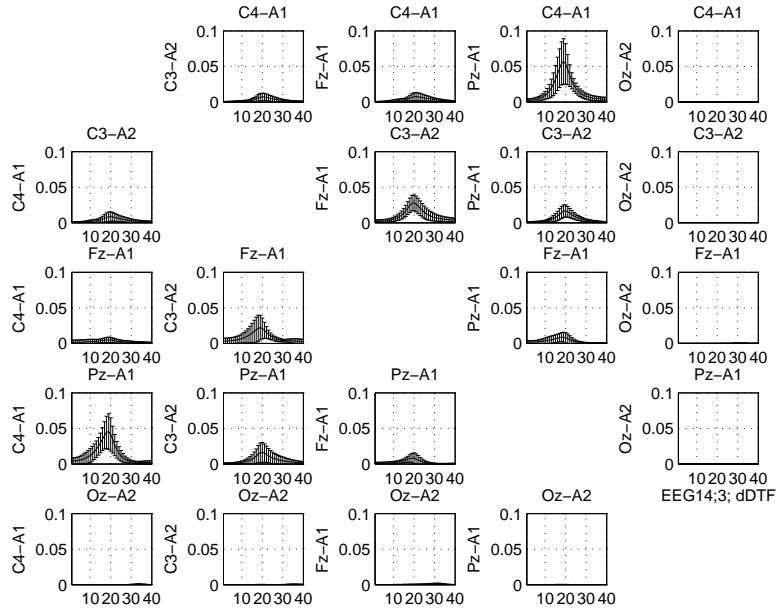


Figure 74: dDTF as in (11): Condition #3 and EEG14. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

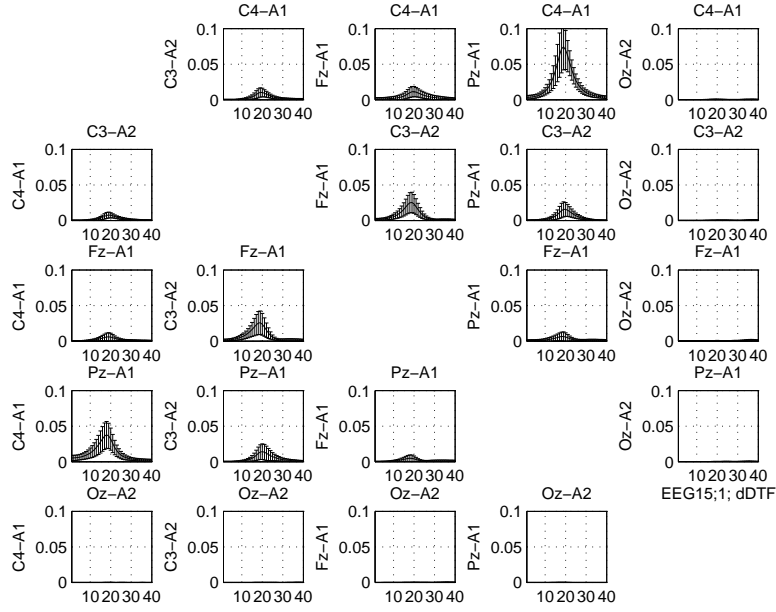


Figure 75: dDTF as in (11): Condition #1 and EEG15. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

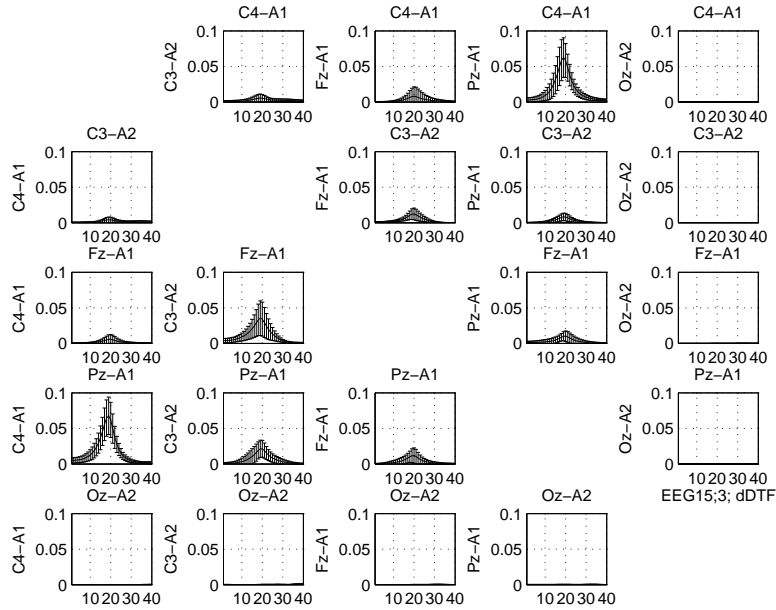


Figure 76: dDTF as in (11): Condition #3 and EEG15. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

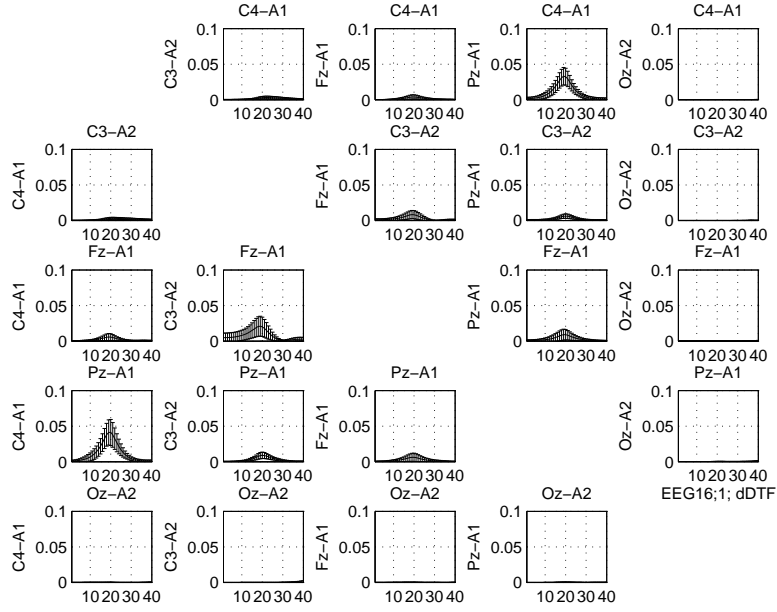


Figure 77: dDTF as in (11): Condition #1 and EEG16. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

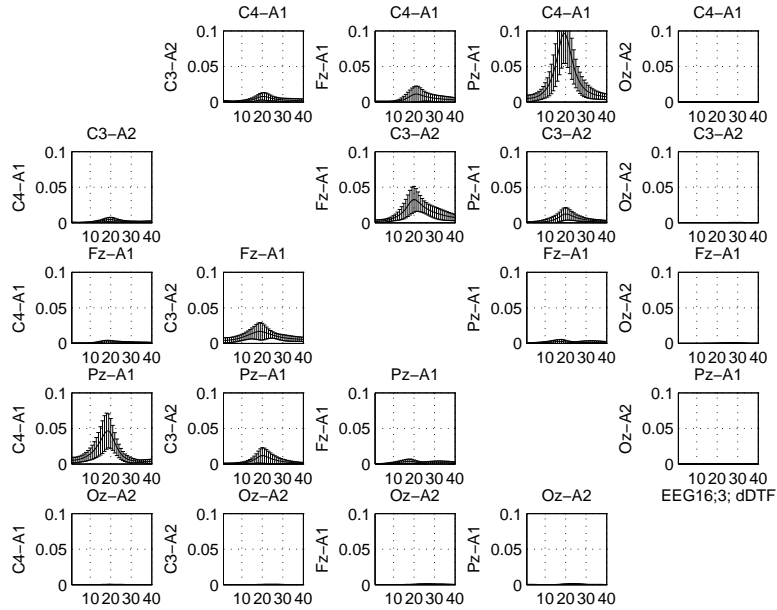


Figure 78: dDTF as in (11): Condition #3 and EEG16. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

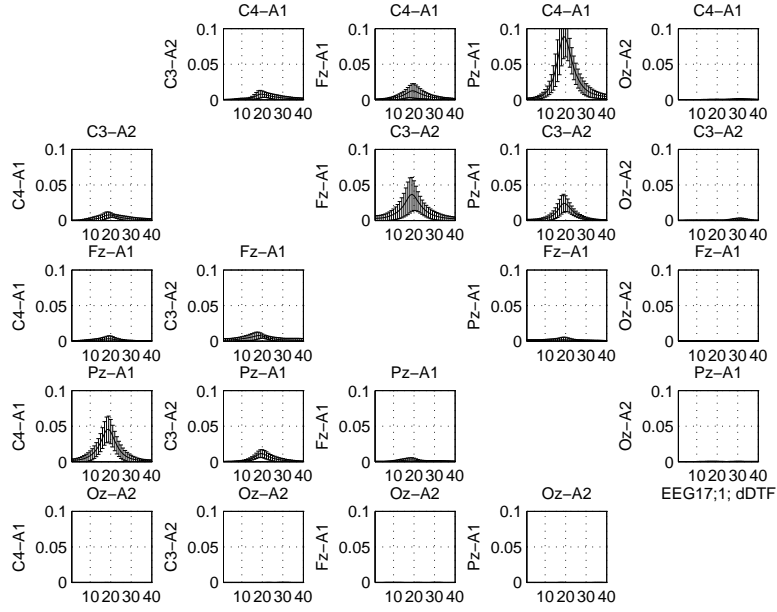


Figure 79: dDTF as in (11): Condition #1 and EEG17. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

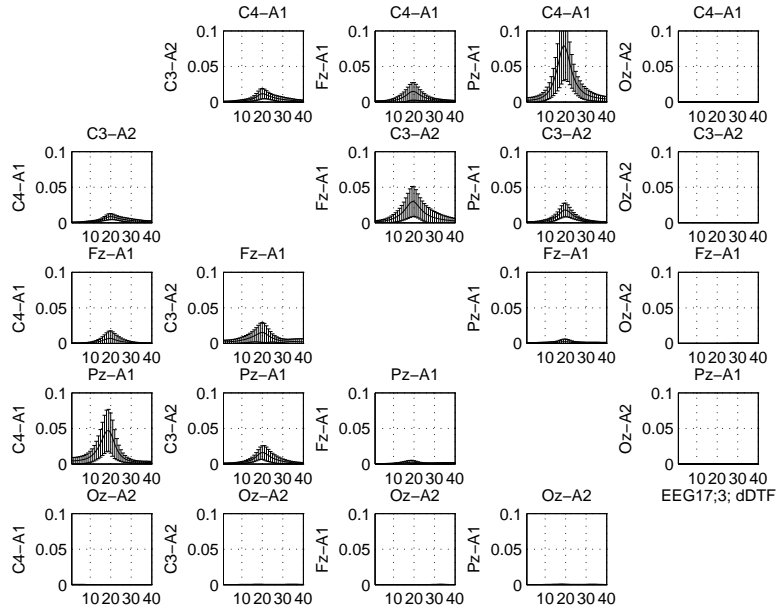


Figure 80: dDTF as in (11): Condition #3 and EEG17. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

3.5 Partial directed coherence (PDC)

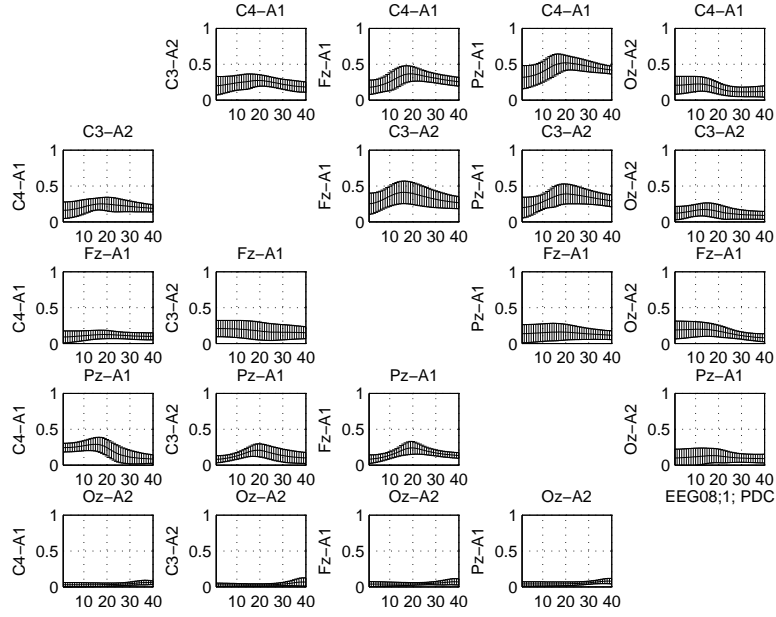


Figure 81: PDC as in (10): Condition #1 and EEG08. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

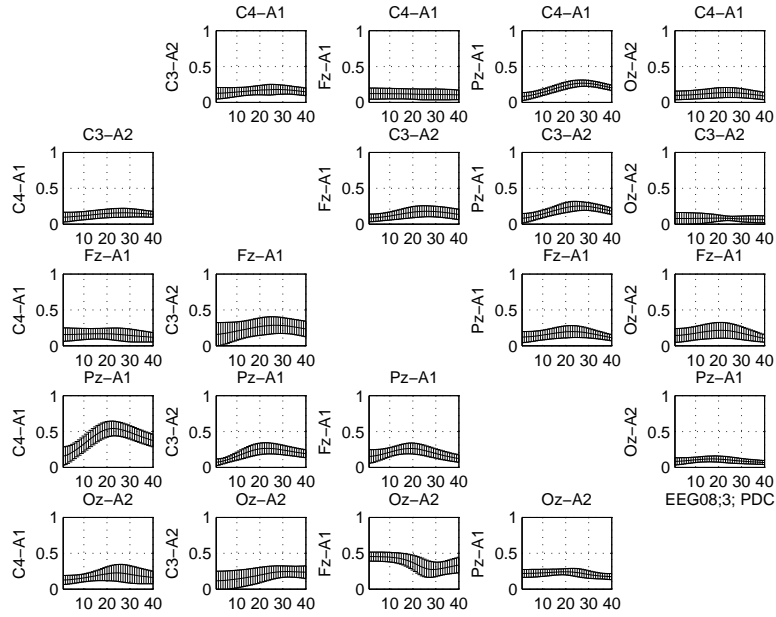


Figure 82: PDC as in (10): Condition #3 and EEG08. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

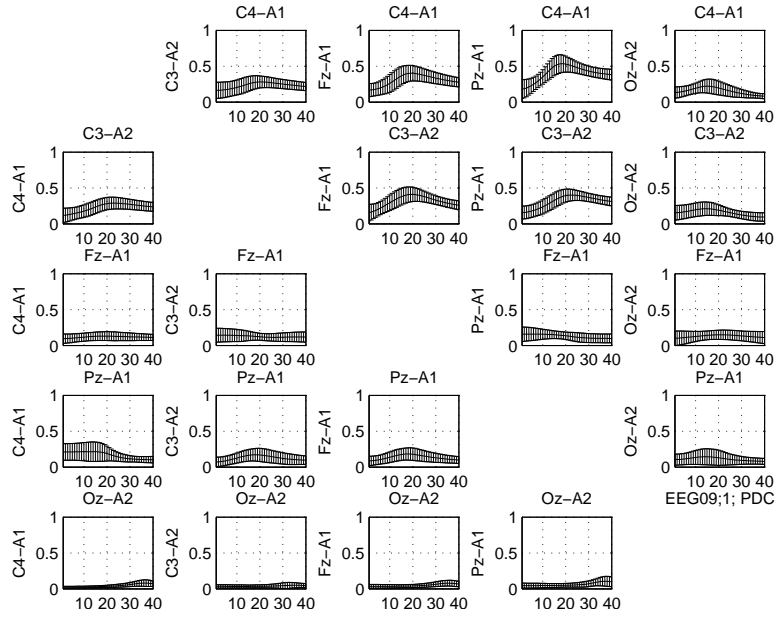


Figure 83: PDC as in (10): Condition #1 and EEG09. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

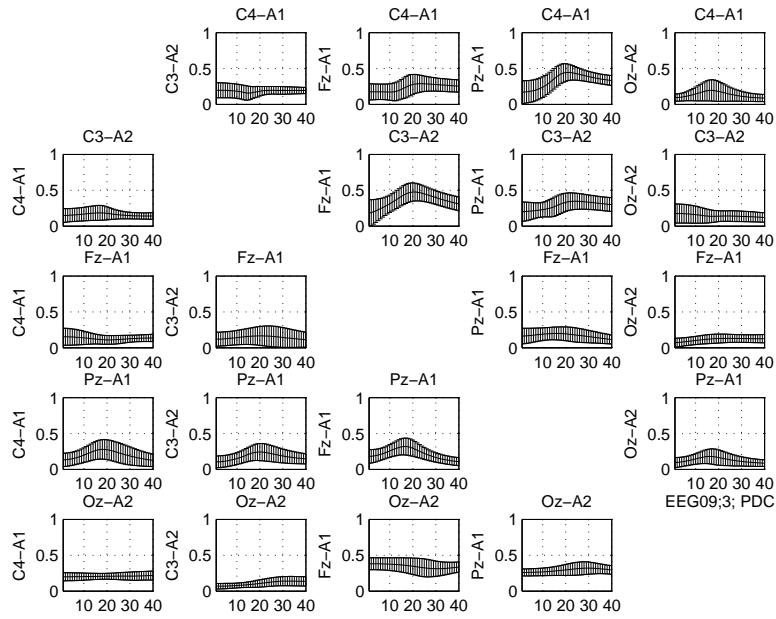


Figure 84: PDC as in (10): Condition #3 and EEG09. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

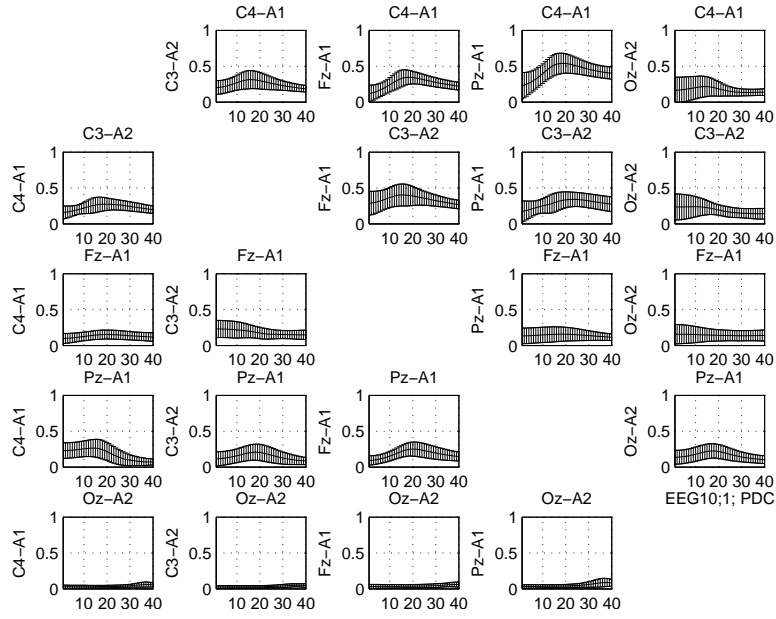


Figure 85: PDC as in (10): Condition #1 and EEG10.X-axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

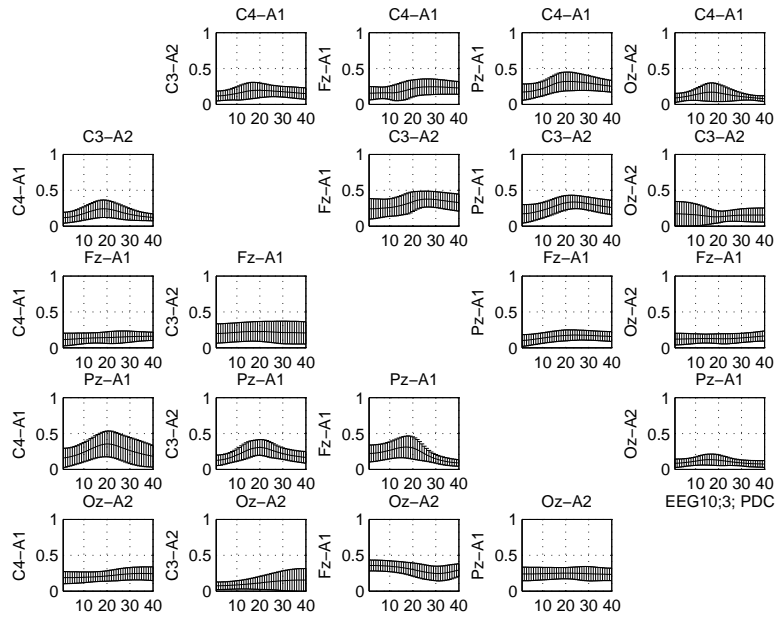


Figure 86: PDC as in (10): Condition #3 and EEG10.X-axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

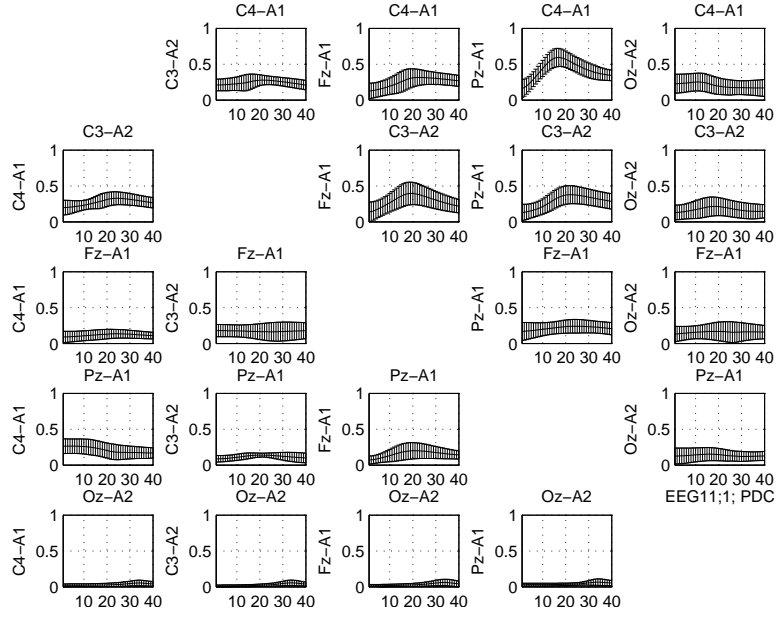


Figure 87: PDC as in (10): Condition #1 and EEG11. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

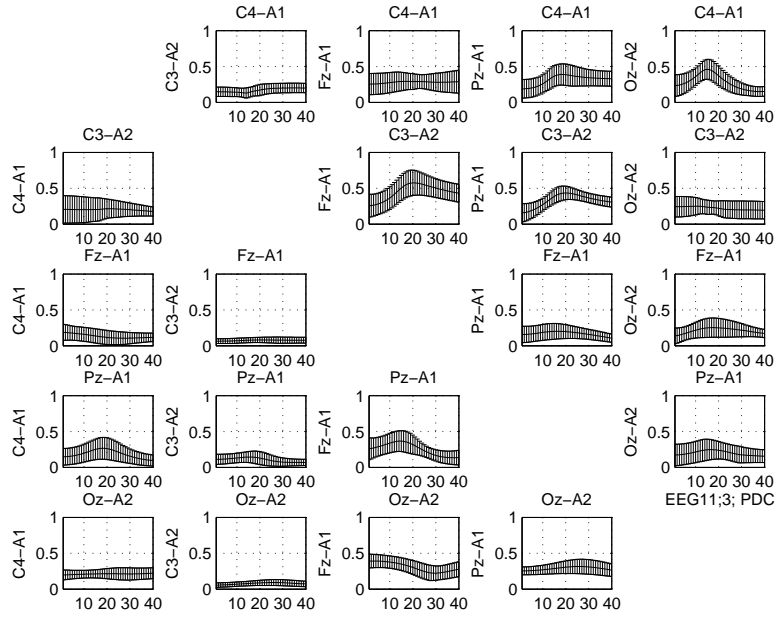


Figure 88: PDC as in (10): Condition #3 and EEG11. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

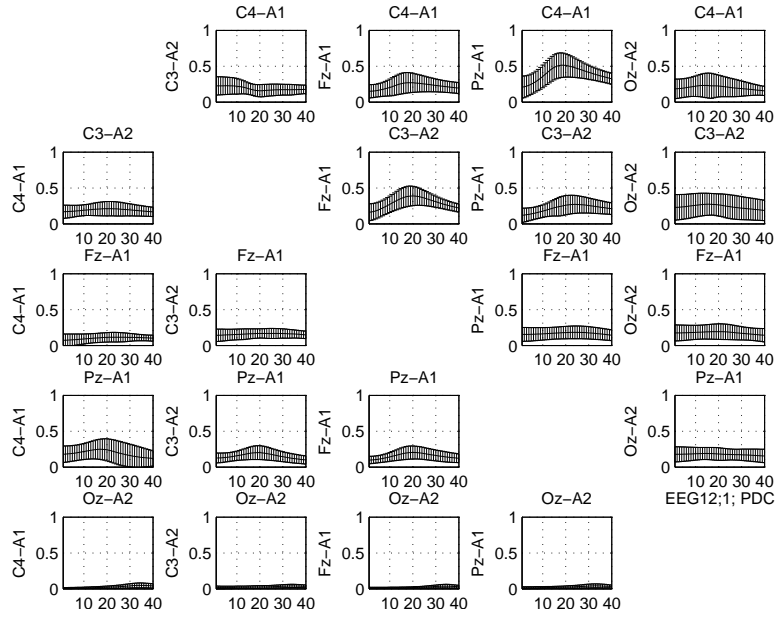


Figure 89: PDC as in (10): Condition #1 and EEG12. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

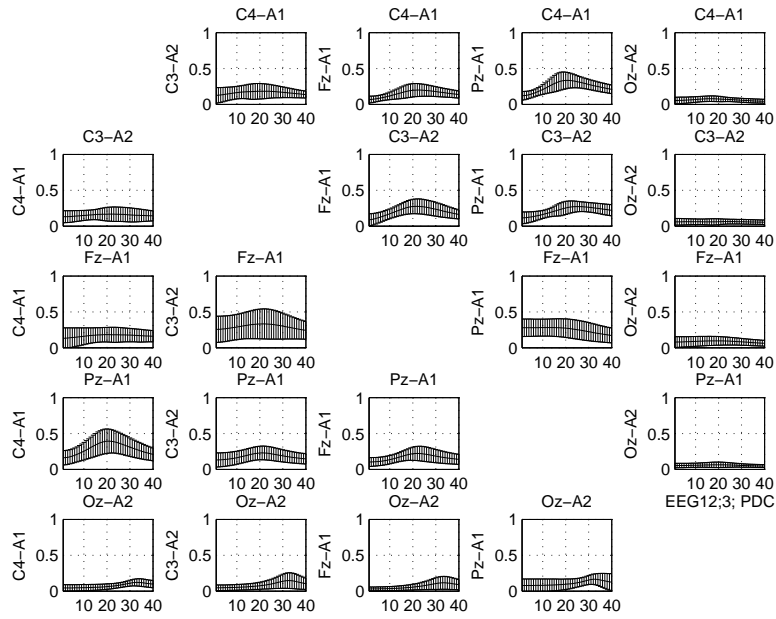


Figure 90: PDC as in (10): Condition #3 and EEG12. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

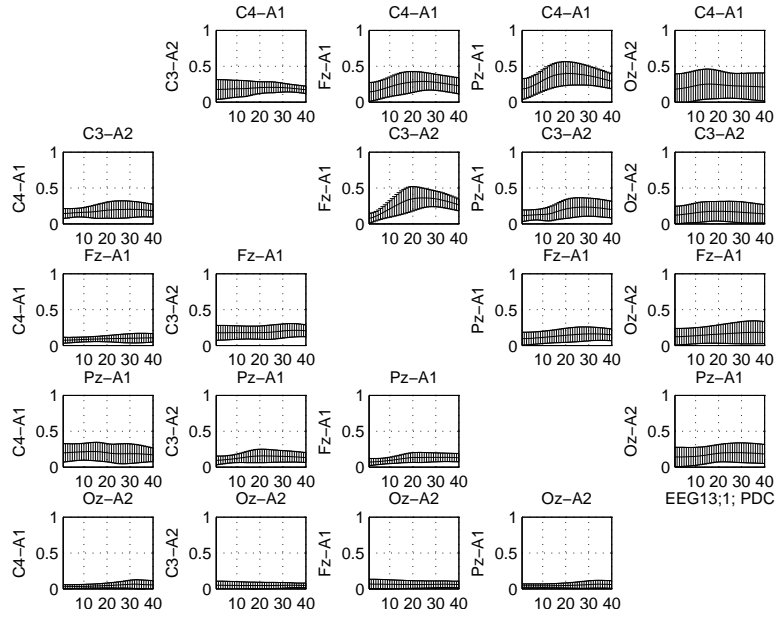


Figure 91: PDC as in (10): Condition #1 and EEG13. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

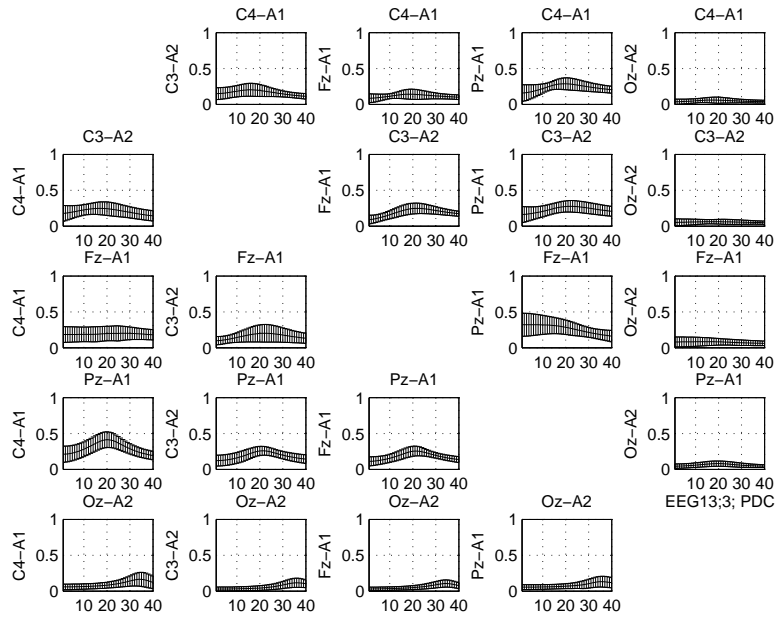


Figure 92: PDC as in (10): Condition #3 and EEG13. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

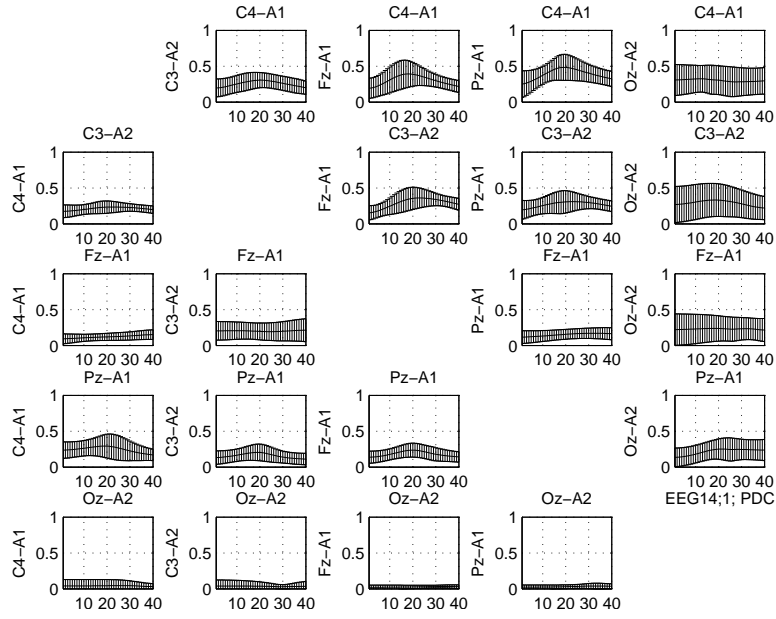


Figure 93: PDC as in (10): Condition #1 and EEG14. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

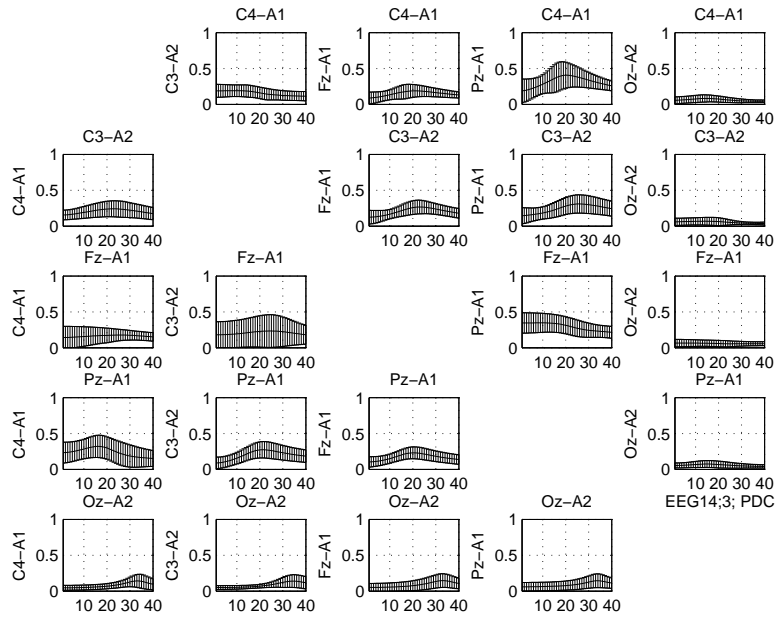


Figure 94: PDC as in (10): Condition #3 and EEG14. *X-axes* in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

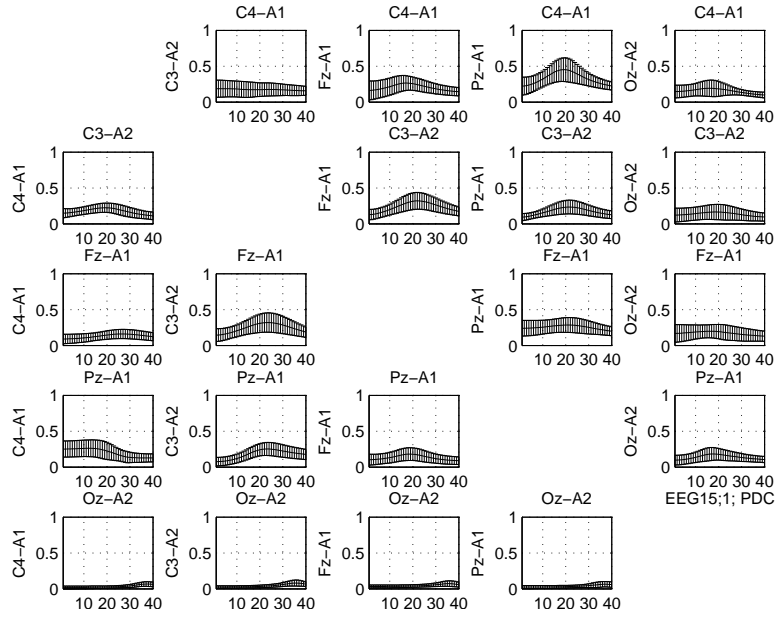


Figure 95: PDC as in (10): Condition #1 and EEG15. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

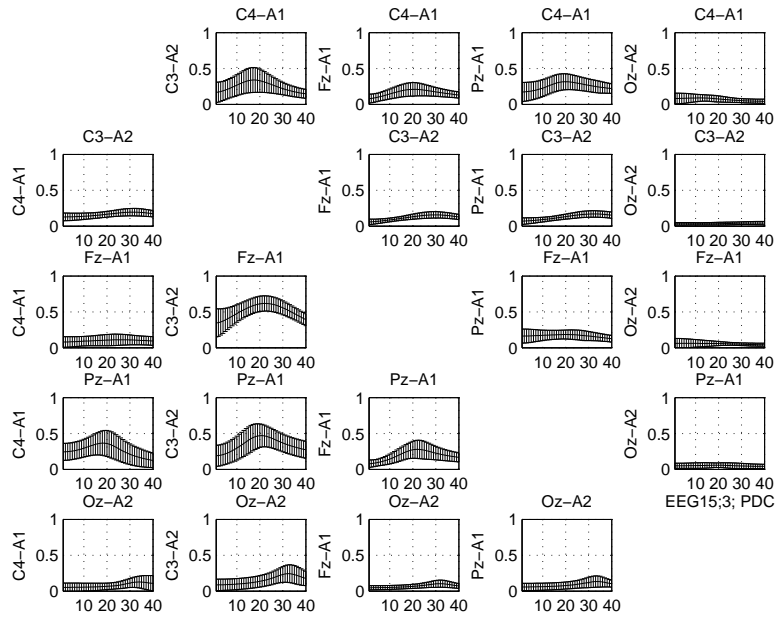


Figure 96: PDC as in (10): Condition #3 and EEG15. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

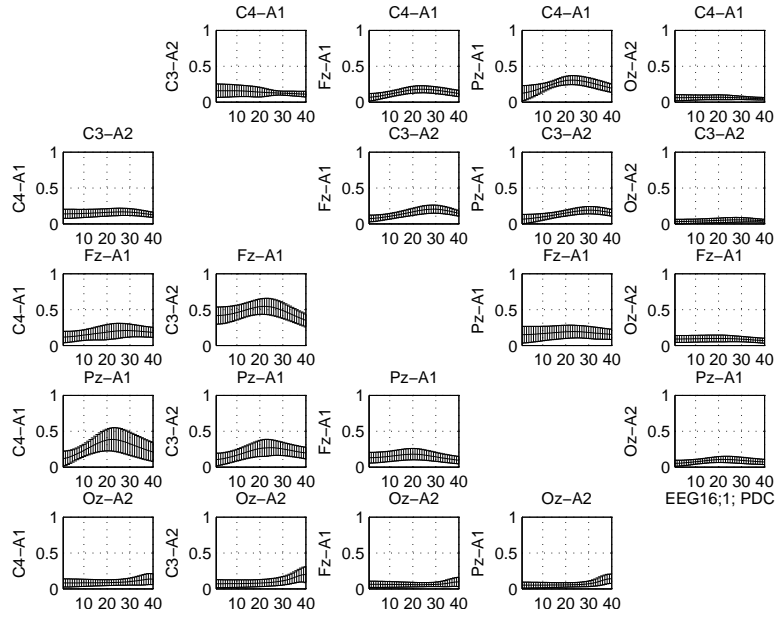


Figure 97: PDC as in (10): Condition #1 and EEG16. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

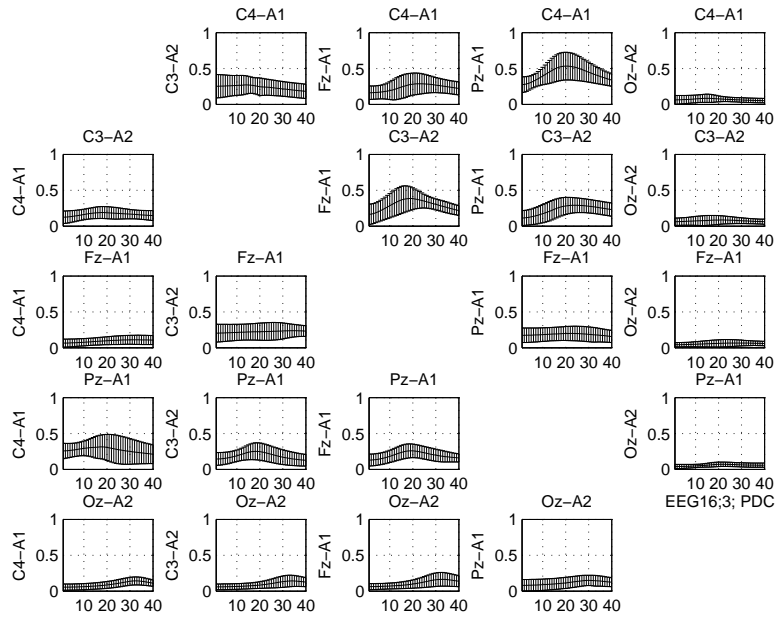


Figure 98: PDC as in (10): Condition #3 and EEG16. X -axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

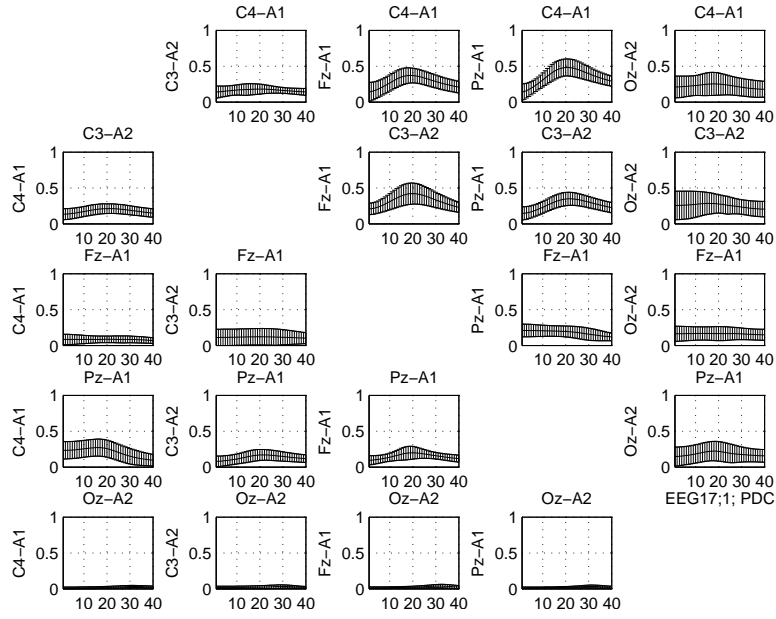


Figure 99: PDC as in (10): Condition #1 and EEG17.X-axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

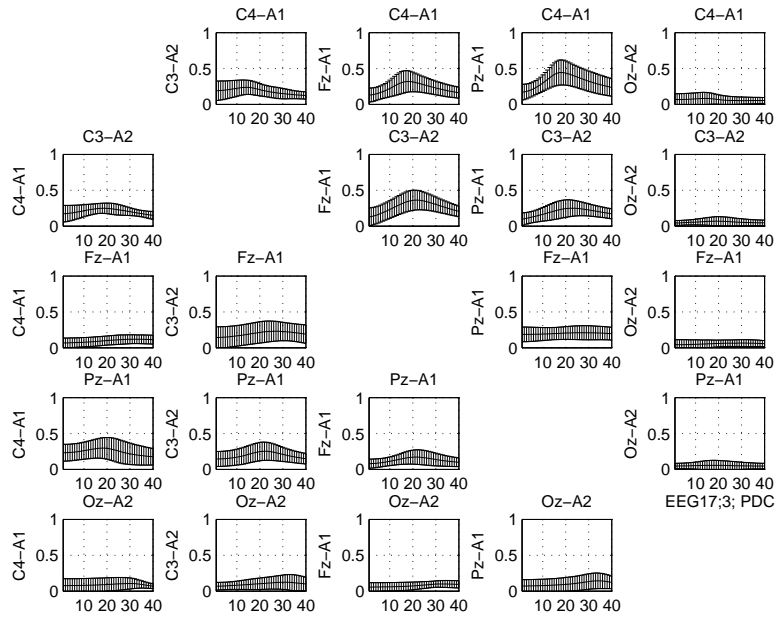


Figure 100: PDC as in (10): Condition #3 and EEG17.X-axes in all plots are frequencies 0 – 20Hz (DC and frequencies around 1Hz are usually filtered by EMD thus no activity there analyzed).

4 Future work

4.1 Statistical analysis of synchrony patterns

Confidence levels of synchrony “patterns” in around 20Hz and around 70Hz to be analyzed.

4.2 Automatic classification/recognition based on synchrony patterns

4.2.1 Two classes of *no-nap* and *40 minute nap* conditions

4.2.2 Trial of clustering/classification of test batteries 8 to 17

References

- [1] K. J. Friston, “Modalities, Modes, and Models in Functional Neuroimaging,” *Science*, vol. 326, no. 5951, pp. 399–403, 2009.
- [2] T. M. Rutkowski, A. Cichocki, and D. P. Mandic, “Analysis of brain responses to musical, steady-state auditory and environmental noise stimuli - A BMI feature extraction approach,” *Neuroscience Research*, vol. 61, no. 1, Supplement 1, p. S252, 2008.
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